Control ENGINEERING

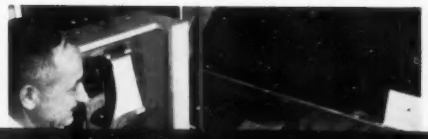
INSTRUMENTATION AND CONTROL SYSTEMS

A McGraw-Hill Publication

75 Cents

MAY 1960

Static Switches Run Sugar Warehouse

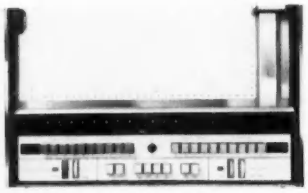


Also in this issue:

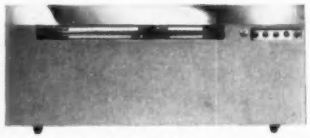
Precision Position Transducers

Stream Analyzer Dynamics

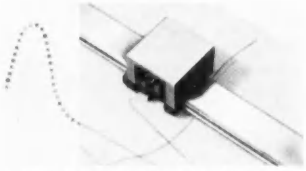
Optimum Response Relay Servos



PUSH BUTTON PANEL controls operations rapidly, even at remote locations.

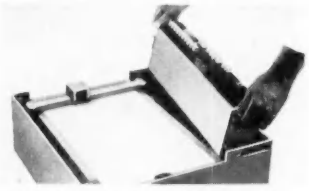


FLAT VACUUM PLATEN assures positive hold down of roll or sheet paper up to 12¼" width. Plot area, standard 10x15".

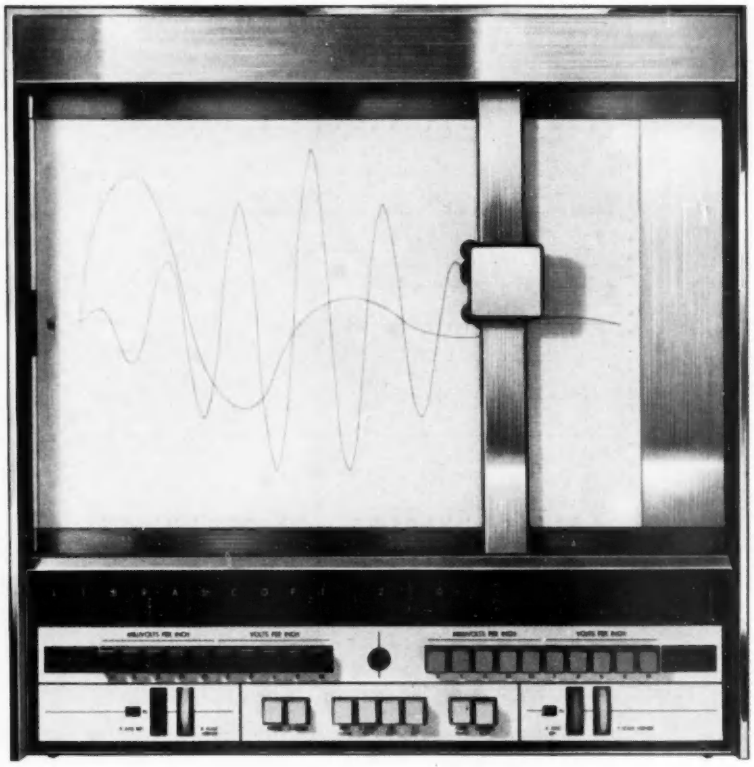


PRINTING FEATURES: Multiple symbol printing head—12 symbols...self contained ink supply.

Pen System—capillary action; splatter-proof. Point joiner available.



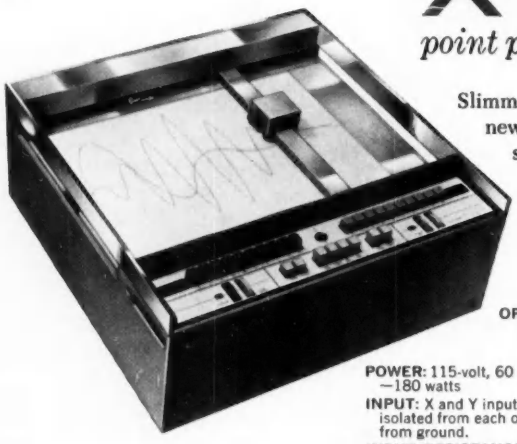
INTERCHANGEABLE MODULES add versatility...interchange with basic control section.



engineered for ease of operation...new

LIBRASCOPE X·Y PLOTTER

point plotting or continuous trace



Slimmer, flatter, push-button fast...Librascope's newest, most advanced plotter is the result of personally-conducted field research by Librascope engineers. Compact design permits rack mounting in groups, saves desk space. Many new conveniences have been added to answer *your* needs.

OPERATING INFORMATION

POWER: 115-volt, 60 cycle —180 watts

INPUT: X and Y inputs isolated from each other and from ground.

INPUT RESISTANCE: 2 megohms nominal on most scales. 1 megohm per volt on .5 millivolts per inch to .1 volts per inch scales.

INPUT SENSITIVITY: .5 millivolts per inch to 50 volts per inch with calibrated push button scales at .5, .1, 5, 10 and 50 millivolts per inch and .1, .5, 1, 5 and 10 volts per inch. Vernier controls permit continuous sensitivity adjustment between fixed scales, permitting full scale plotting for any sensitivity.

ACCURACY: Static .1%, dynamic .2% at 10" per second.

PLOTTER CALIBRATION ACCURACY: .05% on all scales.

SLEWING SPEED: 20" per second.

For full details — dimensions, applications, list of accessory equipment, call our Sales Engineering Department or send for illustrated brochure on Model 210, XY Plotter.

For information on career opportunities at Librascope, write Glen Seltzer, Employment Manager.

GPI LI 9-20

LIBRASCOPE division **GENERAL PRECISION, INC.** • 808 Western Ave., Glendale, California

CIRCLE 217 ON READER SERVICE CARD

Here are America's first six CE-Sulzer once-through boilers: All have L&N Direct-Energy Balance Control.

Company	*Station*	*Operating Pressure (psig)*	*Capability*
Dayton Power & Light Co.	Tait 4	2400	150 MW
Metropolitan Edison Co.	Portland 1	2400	165 MW
Dayton Power & Light Co.	Tait 5	2400	150 MW
Philadelphia Electric Co.	Eddystone 1	5000	325 MW
Cleveland Electric Illuminating Co.	Avon 8	3500	250 MW
Philadelphia Electric Co.	Eddystone 2	3500	325 MW

New L&N Direct-Energy Balance Control Coordinates Once-Through Boiler and Turbine

Philadelphia Electric Company's Eddystone Unit No. 1, the world's highest pressure and temperature (5000 psi and 1200°F) steam generator, employs the largest CE-Sulzer, once-through boiler ever built.

A new type of combustion control, Direct-Energy Balance, coordinates boiler-turbine operation by considering them as an integral unit. From combined steam pressure and generator intelligence, D.E.B. controls regulation of both fuel input and turbine governor valves. Excess air is "trimmed" automatically by flue gas oxygen analyzing equipment.

In the picture above, an operator at Eddystone is using the D.E.B. Control to set directly the desired rate of generation change. When he calls for a change in load, the control responds quickly, at the pre-set rate of change. Operation of the unit is integrated because (1) boiler-turbine output is changed in a predetermined, orderly manner, and (2) output is kept within the capabilities of the equipment in service.

In designing the Direct-Energy Balance method, L&N engineers sought a basic improvement over conventional combustion controls. Based on 30 years' experience in power plant measurements and controls, this new method was developed, subjected to simulation studies, and extensively field-tested. Direct-Energy Balance Control has also been selected for Unit 2 at Eddystone, a supercritical unit of 3500 psi. For information on this new concept in combustion control, call your nearby Field Office, or write for Reprint 463(8) to 4918 Stenton Avenue, Philadelphia 44, Pa.

Direct-Energy Balance Control ... engineered to power plant standards by **LEEDS & NORTHRUP** Instruments Automatic Controls • Furnaces

Control ENGINEERING

MAY 1960
VOL. 7 NO. 5

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

Continued on next page ➧

What's New in the Control Field

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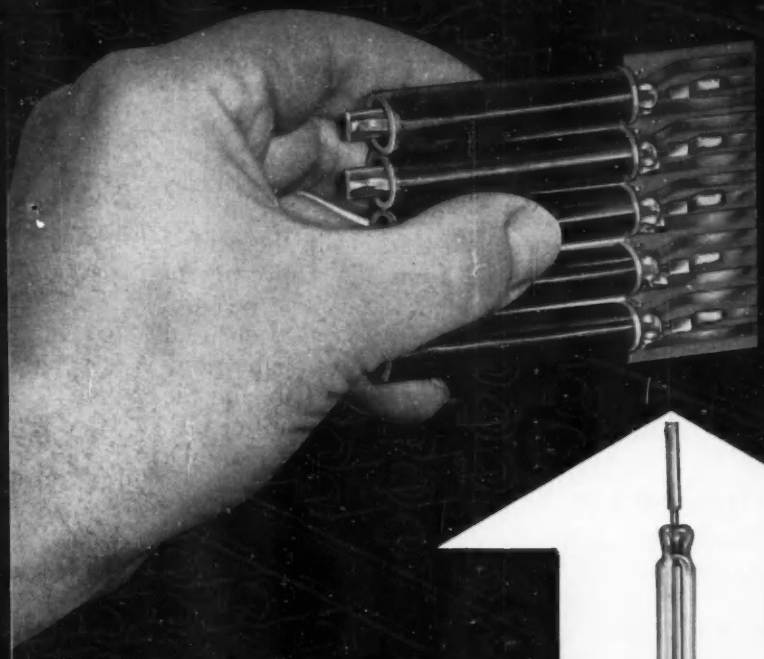
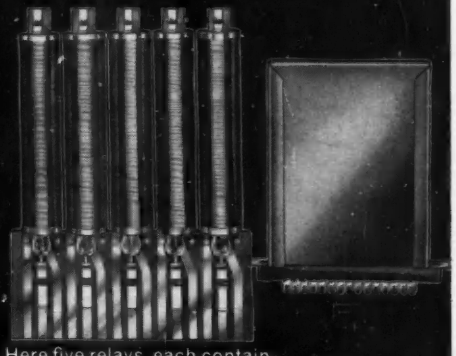
CIRCLE 5 ON READER SERVICE CARD→

CLAREED®

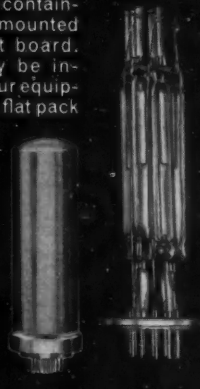
FITS INTO *YOUR* DESIGN!



PACKAGED TO MEET YOUR REQUIREMENTS



Here five relays, each containing two switches, are mounted on a printed circuit board. This assembly may be inserted directly into your equipment or enclosed in a flat pack container.



These six switches are clustered to form the core of a single electromagnetic coil, and encased in a cylindrical steel container.

ACTUAL SIZE

Basic element of CLAREED relays is this switch capsule. A pair of magnetically operated contacts is hermetically sealed in an atmosphere of inert gas. The capsule combines extreme simplicity with high reliability and long life. It has excellent low-level characteristics.

CLAREED Sealed Contact Reed relays put you . . . the designer . . . in the driver's seat. They are simple in design, flexible in assembly. They are packaged and mounted to comply with *your* mechanical design configuration . . . even on your own circuit board. CLAREED relays are ideal components for transistor-drive applications, computers, data-processing and other high speed equipment.

Contacts are hermetically sealed in inert gas. Tens of millions of operations are assured since contact contamination is completely precluded. Hundreds of millions of operations are possible when operated up to ½ rated load.

If you use relays, it will pay you to know all about CLAREED . . . an entirely new concept in relay design. Address C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare Canada Limited, Box 134, Downsview, Ontario. Cable Address: CLARELAY. *Send for Bulletin CPC-5.*

CLARE

When only the best is good enough

SHOPTALK

Optimum response from control teacher

Some time ago we decided that CtE had better bring its readers up to date on the various techniques that have been proposed for optimizing the response of relay servos. Searching for a top-notch author led us to John B. Lewis of the Electrical Engineering Dept. at Purdue University. As you can see from the first of his three-article series, "Optimum Response Relay Servos", p. 125, he responded in optimum fashion.

John has been doing research or teaching in the control field since he received his MS from the University of Tennessee in 1951. With a basic interest in nonlinear control (the subject of his master's thesis), he has worked on wind tunnel controls at Tullahoma. Tenn., digital computer simulation of the SAGE system at MIT's Lincoln Lab, and the analysis of inertial navigation and guidance systems at GE. Instructor Lewis is now teaching and working for his PhD.

Vannah practices what he preaches

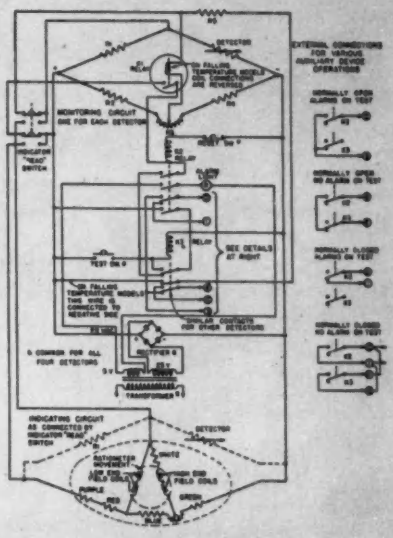
Chief Editor Bill Vannah is usually trying to get industrial publicity men to do a better job of dispensing information about their company's control activities. But as publicity chairman of the Joint Automatic Control Conference, Bill finds the shoe on the other foot. With the responsibility of attracting the best attendance possible to this meeting sponsored by ISA and the control groups of AIEE, ASME, IRE, and AIChE, Chairman Vannah got started by having CtE's art director Jack Gordon design the accompanying symbol and then proceeded to have it spread far and wide. NEMA is running it on their postage meter, other trade organizations are sticking them to their mail. And, oh yes, don't forget to come yourself. It will be well worth your while.

Coming next month

Here's a quick rundown on some of the choice items that will be published in the June issue of CONTROL ENGINEERING: up-to-date application information on acceleration switching servos, the beginning of a series surveying European process control systems, how to reduce the number of diodes in encoding and decoding matrices, dc motor speed control methods, how to heat analyzer sample lines, and many more.

Questions and Answers on the EDISON OMNIGUARD SYSTEM

The Most Effective Means of Measuring and Safeguarding Temperatures and Pressures



Q. How does the Omniguard System work?

A. Edison's Omniguard is characteristically simple and unique in its operation. Each Omniguard channel is a conventional D-C Wheatstone bridge circuit in which an Edison temperature or pressure detector forms the variable leg of the bridge. As the temperature or pressure rises and falls, the detector resistance increases or decreases. An Edison relay (K1) across the bridge senses the current flowing through it. When conditions are normal the current flows in the direction to hold the relay contacts open. When a variation occurs, however, current flow reverses and the contacts of this alarm relay close. Relay K1 energizes the coil of auxiliary relay K2 which actuates an alarm light on the panel face to show which detector is "off-normal," actuates an external alarm or annunciator and maintains the alarm indefinitely – until conditions have returned to normal and the normally closed reset switch is opened.

Any temperature or pressure can be read at any time by pressing the indicator read switch for that point.

Q. Is Omniguard dependable?

A. Reliability is built in. Since each measuring channel is an independent, separate circuit, complete system failure is unlikely. Only the most reliable components are used. Edison resistance temperature detectors don't "drift" over years of service. There are *no* scanning mechanisms to wear out . . . *no* delicate components . . . *no* electronic circuits . . . *no* amplifiers . . . *no* periodic maintenance requirements.

Q. Is Omniguard flexible?

A. Completely. A system can monitor as few as 4 or as many as hundreds of variables. Buy only what you need. Since channels are independent of one another, each can be set to alarm at a different temperature or pressure. Alarm settings can be changed easily and quickly.

Omniguard can be used for alarm or shut down of equipment, alarm can be local and remote, is easy to telemeter to remote control station.

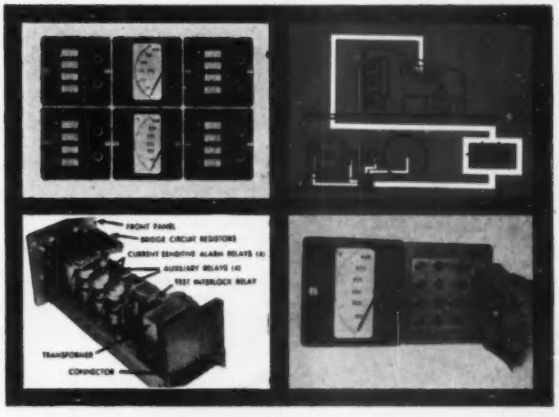
Q. Is Installation economical?

A. Omniguard is the simplest system available. Fewer parts mean lower costs, less maintenance. Plug-in monitors are installed in minutes with no special tools or calibration. Ordinary copper wire connects remote detectors to monitors. Monitor units act as their own annunciators, identify each temperature and pressure, eliminating the need for extra equipment in most installations. Omniguard is a *complete* system with all parts including hardware supplied by Edison.

Q. How accurate are Edison's Resistance Temperature Detectors?

A. In the range from −200°F to +1350°F, no other type of detector is as stable, sensitive, and accurate over years of service. Response times of 0.8 seconds are common – detectors are repeatable to .05% over years of use, resistance being directly proportional to temperature.

Resistance Pressure Detectors are accurate to 1% or better depending on pressure range.



For complete information on the Edison Omniguard System, industry's simplest, most reliable means of continuously monitoring critical temperatures and pressures, write for Bulletin 3036C.

Thomas A. Edison Industries

INSTRUMENT DIVISION

38 LAKESIDE AVENUE, WEST ORANGE, N. J.

Bendix G-20

the new data processing system with the ORGANIZATION CHART *concept*

"Organization Chart" design in the Bendix G-20 means far faster, more efficient processing of scientific and business problems. The reason is clear:

The electronic manager of every data processing system is a computer. But most are poor "bosses" because they cannot delegate authority, or even supervise more than one operation at a time. Many computers run operations as complex as your own business, but with an inefficiency that you would never tolerate. Bendix engineers saw this shortcoming, and turned for a solution to the organization chart common to any well-managed business.

The G-20 Central Processor, or computer, has a staff of well-taught subordinates that can take instructions from the "boss" and go to work on their own, directing the workers that perform such tasks as reading punched paper tape and cards, looking up data on magnetic tape, and printing results. The "boss" can direct numerous subordinates, and without human intervention, schedule the work for each, making sure the most important work is done first. While the subordinates handle the details, the Central Processor is free to do the all-important computing.

This "organization chart" delegation of authority means several operations may be performed simultaneously, and with a minimum of equipment. The results? Call it "low cost per operation", or "just plain efficiency", but it is all the same... the Bendix G-20 gives you more performance per dollar than any other data processing system. The actual performance specifications listed at the right show the tremendous speed and power of the G-20. Components and design are the most modern in the industry today. System sizes can vary from a medium-scale system to a very large system with remote on-line or off-line sub-systems. Write for complete descriptive literature.

BENDIX AVIATION CORP., COMPUTER DIVISION Dept. W25 Los Angeles 45, California

SPECIFICATIONS:

MEMORY: Core, to 32,768 words in 4096 word modules.

EXECUTE +: 7 μs. avg., fixed point, one-word precision. 13 μs. avg., floating point, one-word precision.

EXECUTE ×: 49 μs. avg., fixed point, one-word precision. 49 μs. avg., floating point, one-word precision.

ARITHMETIC: Built-in floating pt., 12 dec. digit precision.

CIRCUITRY: Solid-state; parallel; 2.5 kva.

PROGRAMMING: Symbolic assembler or algebraic compiler.

INPUT/OUTPUT: 165,000 char./second max., asynchronous.

MAGNETIC TAPE: 120,000 decimal digit/second read-write.

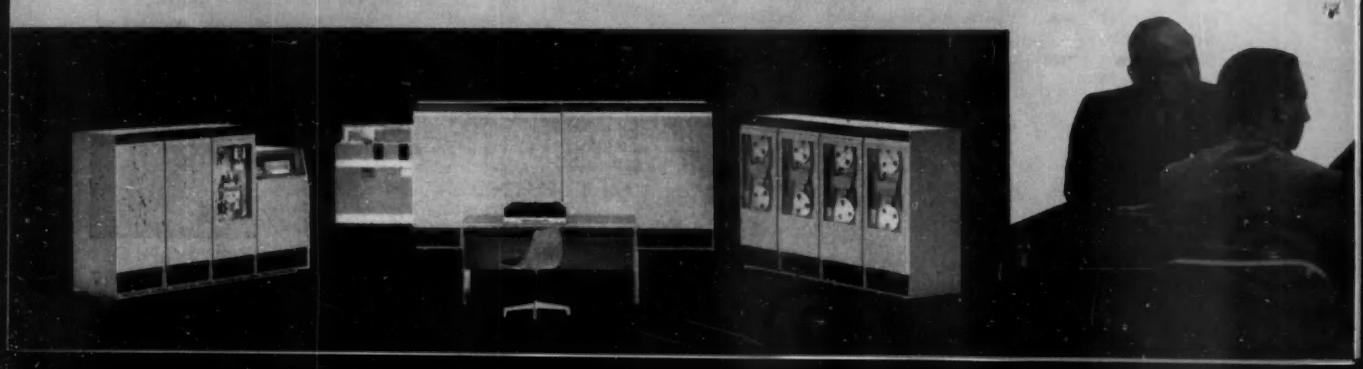
LINE PRINTERS: 600 lines per minute.

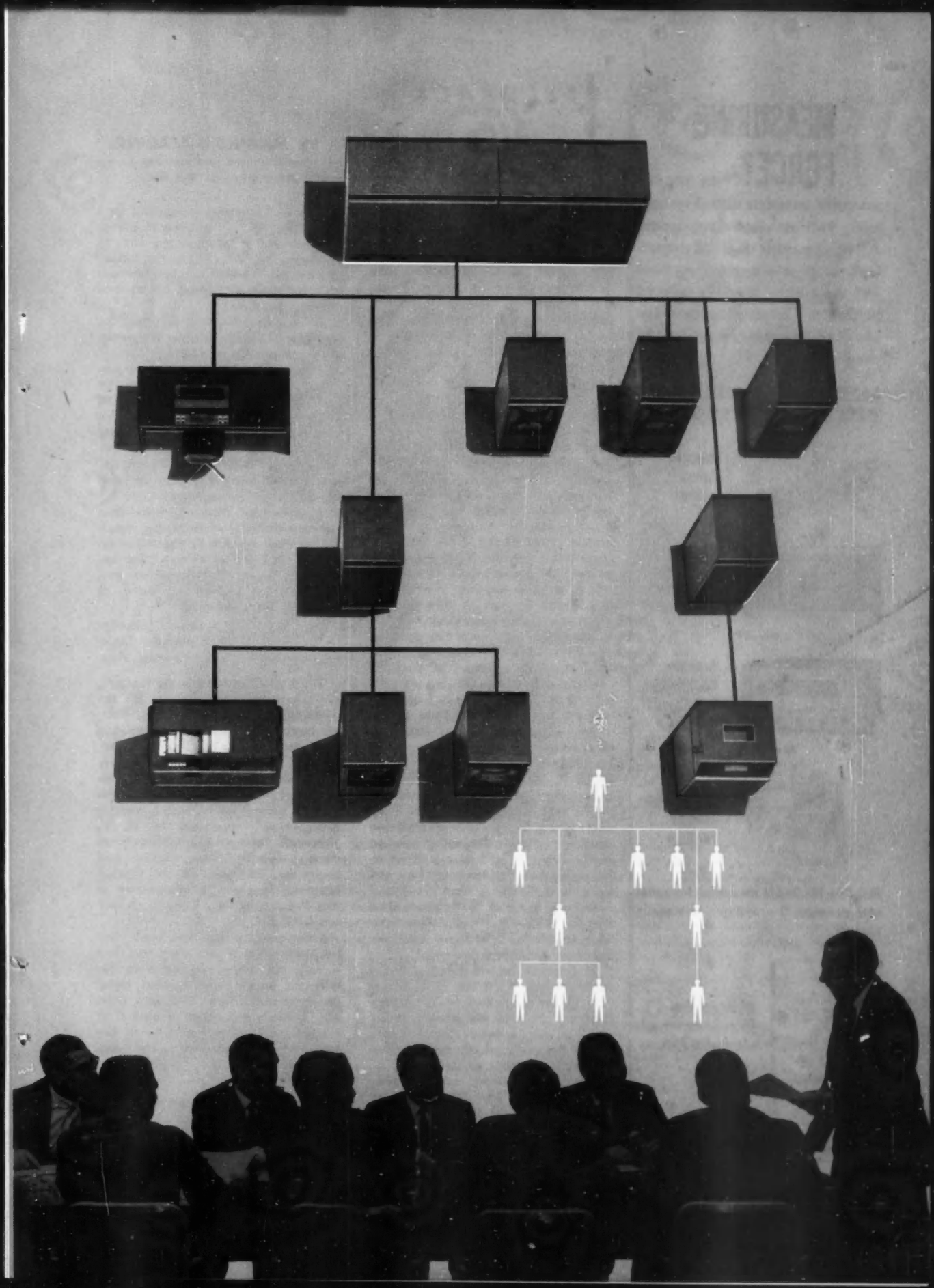
PUNCHED TAPE: 500 or more character/second readers. 100 or more character/second punches.

PUNCHED CARDS: Standard high-speed 80 column units.

CONTROL BUFFERS: 1024 character memory for data and commands. Controls transmission on-line or off-line.

CIRCLE 8 ON READER SERVICE CARD





FEEDBACK

OPTICAL VS MAGNETIC READING:

Two expert comments here and another noted elsewhere add more wood to the fire.

Some heat on magnetic reading

To the Editor—

The January issue of CtE (pages 48-53) contained an article entitled "Optical Versus Magnetic Reading" written by Lewis H. Young. I am not going to extol the virtues of magnetic reading, nor am I going to attempt to point out the faults of optical reading. I do, however, feel that there are several statements on page 50 which tend to be misleading.

First let us take the statement that many commercial printers cannot meet the requirements for accuracy in magnetic printing. Working at our computer laboratory in Palo Alto for the past two years, I had the opportunity to observe first hand the ability of printers to meet the ABA specifications. In all but a few instances commercial printers have been able to meet the requirements after a brief education and training period. It should also be realized that the machine manufacturers are constantly improving their equipment in order to expand printing specifications. The most recent enlargements of the ABA (American Banking Association) took place a few months ago and are now available in ABA Publication #149.

The second thing is the statement that oxide content of printing must be held to 5 percent. Mr. Young might be referring to either of two things, the signal level of the printing or the oxide content of the ink. Actually there is no ABA specification covering the oxide content of printing itself. There is, of course, a direct relationship between oxide content and signal level. If this is what Mr. Young is referring to, it should be made clear that the ABA specifications allow from 50% to 200% of the signal level produced by a standard document.

If, however, he was referring to the oxide content of the ink itself, this is very closely controlled by the manufacturer. Normal ink manufacturing practices provide better than 5% control of the chemical contents whether the ink is magnetic or standard.

Another statement mentions trouble in holding tolerances of a few thousandths of an inch. It is quite true that there are close tolerances on line width, spacing, extraneous ink, etc. It must, however, be kept in mind that these specifications were not decided on by the machine manufacturers alone. They were formulated by a joint effort of the equipment manufacturers and a group of experienced commercial printers. It is the feeling of these printers that the specifications are consistent with good commercial printing practices.

To say that there is no need for specifications when printing with magnetic ink would be wishful thinking. We have realized the necessity for providing assistance to banks and printers who are becoming involved in printing electronically read documents. We now have a Magnetic Ink Printing Evaluation Center in operation specifically for this purpose. This is the same center which has been assigned by the Bank Management Commission, American Banking Association the responsibility of supplying standard printing samples to the entire industry. We would welcome the opportunity to supply information and assistance to anyone interested in Magnetic Ink Printing.

John E. Pawlitz
GE Computer Dept.
Deer Valley Park, Phoenix, Ariz.

We'll give "equal time on the air", but no commercials, please. It's encouraging to know that machine manufacturers and commercial printers have agreed on specifications, but apparently dimensional tolerances are still a difficulty. As authority for this statement of difficulty we cite "An Interim Report on Optical Character Recognition", presented by H. F. Sherwood, manager of retail data processing, Touche, Ross, Bailey and Smart and chairman of the Optical Scanning Standards Subcommittee of the Retail Research Institute before the RRI, Feb. 11, 1960.

Great progress has been made, but for justification of our stand that this is only the beginning, we note the following expert opinion that input preparation still lags. If it does, then Mr. Young's evaluation of optical vs magnetic reading was well worth the four columns it occupied in the January issue. Ed.

Input preparation lags.

To the Editor—

Regarding "Optical Versus Magnetic Reading," p. 48, Jan. 1960 issue, those of us who have witnessed an astounding five generations of business

THOR
MACE
TITAN
HAWK
ATLAS
SNARK
NIKE B
BOMARC
NIKE ZEUS
SPARROW I
SPARROW II
SPARROW III
NIKE HERCULES
SIDEWINDER
REGULUS II
VANGUARD
REDSTONE
JUPITER C
PERSHING
BULL PUP
MERCURY
TERRIER
POLARIS
TARTAR
CORVUS
FALCON

N/D Designs Assembly Savings Into Critical Miniature/Instrument Ball Bearings!

Helping customers *simplify* instrument assembly is a specialty of the N/D engineering group. How? Through *creative* Miniature/Instrument ball bearing application and design. Often, a new ball bearing design will produce assembly savings in excess of its additional costs. Integral ball bearings, too, very often cut down difficult and costly hand assembly of shaft and parts.

A timely example of N/D customer assembly savings can be seen in Nike Ajax and Hercules missile ground support. Here, *special* N/D Instrument ball bearings are now used in precision potentiometers. New Departure engineers recommended eliminating two *single row* instrument bearings, mounted in duplex and requiring precision spacer and separate guide roller. They replaced this assembly with a *special* N/D *double row* high precision instrument ball bearing with integral outer race guide roller . . . and shaft mounted with a nut. This *one* recommendation produced cost savings of over 400%! In turn, the customer was able to reduce the potentiometer selling price to the government. What's more, the New Departure Instrument Ball Bearings improved potentiometer reliability!

You can look to minimum assembly costs and unsurpassed *reliability*. Include an N/D Miniature/Instrument Bearing Specialist in your early design level discussions. For immediate information or assistance, call or write Department L.S., New Departure Division, General Motors Corporation, Bristol, Connecticut.

NEW DEPARTURE

MINIATURE & INSTRUMENT BALL BEARINGS

proved reliability you can build around

and scientific computers in almost as many years can't help being only slightly enthusiastic about the barest of advances in input preparation. Furthermore, there are enough indications that near-future lines of automatic input equipment can be properly utilized by only a very small segment of industry, e.g., perhaps 5 percent of the banks, for magnetic ink check reading, and comparable percentages in other industries utilizing either magnetic or optical scanners.

While there are many engineering problems involved in properly designing and building reliable character reading devices, the combination of high hardware costs, nonmodularity, insufficient or borderline volumes, and low operating efficiencies resulting from poor print and document quality, etc.—to cite just a few of the factors needy of consideration—makes even the "quality" engineered device of questionable commercial value. In order to reduce the per-unit cost of automatic document preparation, a number of code reading techniques have been recently suggested. The advantages that might be realized in some cases must be balanced by the need for dual reading areas that are commonly introduced.

The small fraternity of potential character reading equipment users may claim that they process the greater preponderance of paper, and thus mechanization of their operations will cut widely into rising operating costs. Nevertheless, it is evident that the input problem will continue to exist until a time when a more widely applicable and feasible solution can be evolved and demonstrated.

Jordan D. Kassan
Consulting Engineer
Poughkeepsie, N. Y.

Info, please—glass rod memory

In answer to a telephone request for more information on the National Cash Register Co. glass rod memory (pages 38 and 40, Oct. 1959), our Los Angeles news editor, Michael Murphy, has reported that readers should contact L. J. Hines, marketing manager, NCR, 1401 E. El Segundo Blvd, Hawthorne, Cal. NCR will soon publish a technical brochure, Report No. 6001, entitled "Rod Memory". For a user's reaction to the memory, contacting P. Hilker, Data Reduction Center, Naval Ordnance Test Station, China Lake, Calif. Ed.

GPS COMPUTER AT HAMILTON STANDARD, BROADBROOK, CONN.

Simulation Studies of Hydrofoils at HAMILTON STANDARD ELECTRONICS

The Electronics Department of Hamilton Standard Division, United Aircraft Corporation is designing stabilization and control systems for hydrofoil craft. The GPS Statistical Analog Computer is the one being used in the system optimalization. The wealth of practical experience that Hamilton Standard Electronics has acquired in stabilization control of helicopters is being applied to the stability control problems of hydrofoil craft.

Dynamic characteristics as well as the performance of the CONTROL-HYDROFOIL system in the presence of random disturbances caused by complex wave motion over the full range of sea state conditions are being examined. Dynamic and probabalistic responses are generated simultaneously and directly on the GPS Statistical Analog Computer with a considerable savings in time and manpower.

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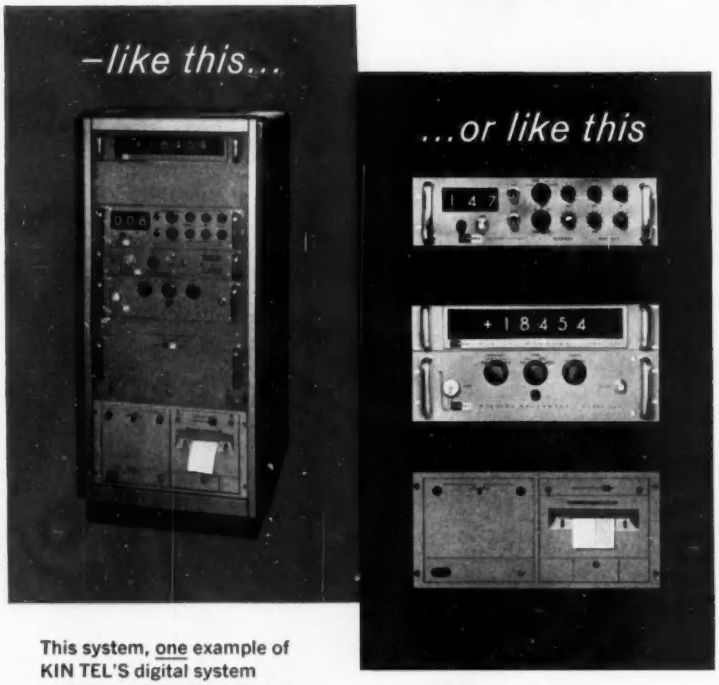

This system, one example of KIN TEL'S digital system experience, takes eight measurements at each of 7200 different data points. Outputs include visual readout, digital printer, X-Y recorder, and tape punch. Tape is perforated for direct entry into a digital computer. To provide 0.01% accuracy for low-level inputs, alternate channels scan calibration signals. These, with the unknown input signal, are fed to the computer and correction is made for any inaccuracy in the system itself. Cost: about $20,000.

This data system consists of a KIN TEL 453M scanner and 501 DC digital voltmeter, plus a parallel entry printer. Briefly, the system will accept 400 one-wire, 200 two-wire, or 100 four-wire inputs, and will provide both visual and printed indication of the channel being scanned and DC input signals from ±100 microvolts to ± 1000 volts. Accuracy is 0.01% ±1 digit, and ranging and polarity indication are automatic. The complete system costs approximately $6850. At the present time, delivery is off the shelf.

KIN TEL DIGITAL SYSTEM CAPABILITIES

You can have any number of channels: A single 453M scanner ($2500) accepts 400 one-wire, 200 two-wire, or 100 four-wire inputs. Additional scanners can be added if more inputs are required.

You can measure DC from ±1 μv to ±1000 volts: The KIN TEL 501 DC digital voltmeter ($2995) measures from ±100 μv to ±1000 volts. Addition of a KIN TEL digital preamplifier increases sensitivity to 1μv DC.

You can measure AC from 10 μv to 1000 volts: Addition of a 452 AC converter ($850) to the 501 DC digital voltmeter permits measurement of RMS AC voltages from 1 mv to 1000 volts in the frequency range of 30 cps to 10 kc. A KIN TEL preamplifier can be added to increase AC measurement sensitivity to 10 μv from 30 cps to 2 kc.

You can measure DC/DC and AC/DC voltage ratios: The 507B digital voltmeter/ratiometer ($3835) measures DC voltages from ±100 μv to ±1000 volts and DC/DC ratios from .0001:1 to 999.9:1. Accuracy is 0.01% ±1 digit. Addition of an AC converter permits AC/DC ratio measurements.

You can get 0.01% DC and 0.2% AC accuracy: The KIN TEL 502 AC/DC digital voltmeter ($3845) measures DC from ±100 μv to ±1000 volts with 0.01% ±1 digit of reading accuracy; and AC from 1 mv to 1000 volts, 30 cps to 10 kc, with 0.2% of full scale accuracy.

You can have 10,000 megohm input impedance: The KIN TEL 458A digital voltmeter preamplifier ($1225) has gain positions of 100 (for DC and 30 cps to 2 kc AC measurement) and +1 HI Z (for DC only). On the +1 gain position input impedance is >10,000 megohms and gain accuracy is 0.001%. Input range for +1 operation is 0 to 40 volts.

You can have visual, printed, or any other form of output: KIN TEL digital voltmeters provide visual indication of the measured quantity on a single-plane in-line readout. They are capable of directly driving commercially available 10-line parallel input digital printers. Converters are available for driving other types of printers, paper tape punches, typewriters, and IBM card punches.

To find out how a KIN TEL digital system can solve your particular data acquisition problem, send us an outline of your requirements, or contact your nearest KIN TEL engineering representative.

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Harold K. Cheney
barnstormed into flight test

In the 1930's aircraft designers relied almost completely on test pilots for performance feedback. That's why Vultee Aircraft officials were startled one spring day when a visiting Turkish delegation interested in buying Vultee bombers asked to talk to the company's flight test engineer. Eager to keep customers happy in an era of lean business, Jerry Vultee hustled over a bright young engineer fresh from Cincinnati University's Aeronautical Engineering Department—he was Vultee's idea of what the Turks probably thought a flight test engineer would look like. Harold K. Cheney first learned he was the company's flight test specialist as he was introduced to the visitors.

Such an introduction didn't overwhelm Cheney, who had been an aerial barnstormer at the age of 15 and who had soloed at Love Field, Texas, at 16. He glibly told the delegation why the Vultee ship outperformed anything in its field, outlined a test program to confirm contract performance values. His own officials were so impressed that he's been in the flight test business ever since.

Test instrumentation, Cheney reminisces, has come a long way since those early days. And he has done a lot of reminiscing as he has helped put together the program for the Sixth National Flight Test Symposium to be held in San Diego this month; Cheney is general chairman. An example of what used to be: in 1937 when he had to get additional data on the lateral control characteristics of the PT-13, a Vultee pursuit ship, Cheney found himself ensconced in the rear cockpit with a primitive hand-operated rig.

"I'd tell the pilot to stabilize the aircraft," he recalls, "and when he had, I'd apply a side force with a 'fish scale' hooked around the control stick. Holding the deflection, I'd read the force on the fish scale and look out at the aileron to see how many painted marks were visible. After returning control to the pilot, I'd jot down on a knee pad the pounds of force and the resulting deflection."

Colorful data collection techniques like that were destined to have a short life as the thirties came to a close. The industry was designing greater performance into aircraft, particularly military airplanes, and data was needed more precisely and in greater volumes. As part of solving this problem, to check out another Vultee pursuit ship, Cheney developed in 1939 the first flight test photorecorder.

Cheney's flight test group at Vultee was also the first to use telemetry as a method of acquiring flight data. The pioneering effort was on Vultee's A-35 dive bomber—to obtain dynamic data on the buffeting characteristics of the aircraft during a high speed drive.

When Vultee merged with Consolidated Aircraft in 1943, Cheney became the Vultee Div.'s flight test chief. Later that year he was sent back to Consolidated Vultee's Nashville (Tenn.) plant.

While in Nashville he met another aviation enthusiast, Virginia Hawkins, then an American Airlines stewardess flying the Nashville to New York run, and he married her before he returned to California.

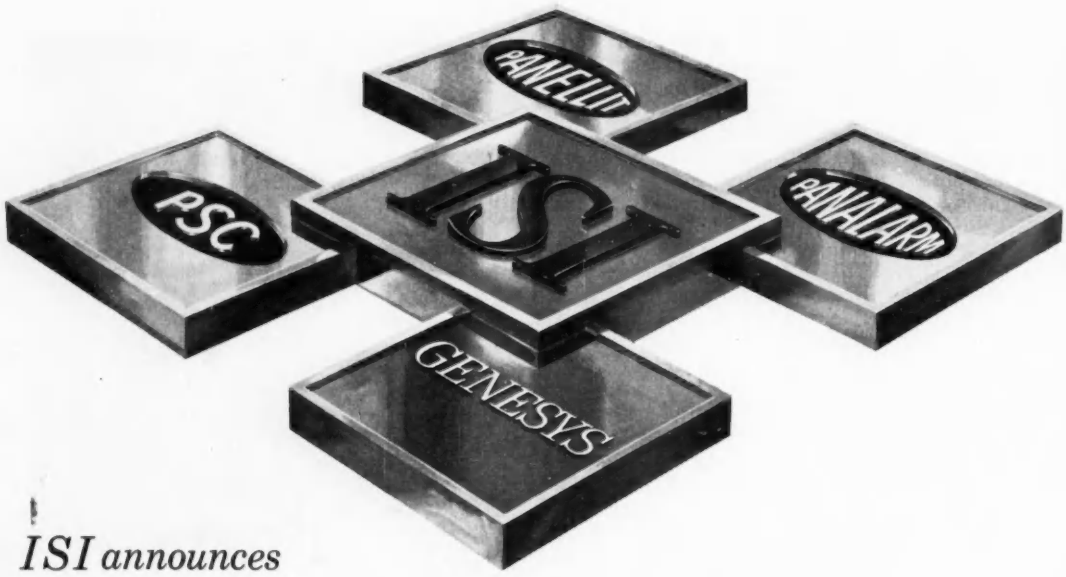
At the end of the war, Cheney was named chief missile test engineer of Consolidated Vultee's San Diego Div. (the name has since been shortened to Convair and it's a division of General Dynamics Corp.). For seven years he worked with missles when, as he puts it "the missile business was fun," meaning even more unpredictable and exciting than it is today. Cheney worked on the MX-744 (forerunner of ICBM Atlas) and the prototype models of Lark and Terrier.

One of his most satisfying experiences happened in 1946 when his group achieved what is believed to be the U. S.'s first guided missile flight. A Lark missile was manually guided by SC 584 radar tracking information presented on a plotting board toward a balloon-supported target. Cameras mounted in the missile's nose indicated that the bird passed within 13 feet of the target.

Cheney switched back to aircraft flight testing in 1954 when he was made chief flight test engineer at Convair-San Diego. Here he worked on the flight testing of the Convair 340 civilian transport and the F-102 and F-106 supersonic fighters.

Today Cheney's chief responsibility is developing future flight test program requirements. In addition, right now he's helping in the final flight testing of Convair's new 880 jet transport which, as the world's fastest commercial transport, is a far cry from the Vultee bomber, Harold Cheney's first flight test subject.

Today's big news in



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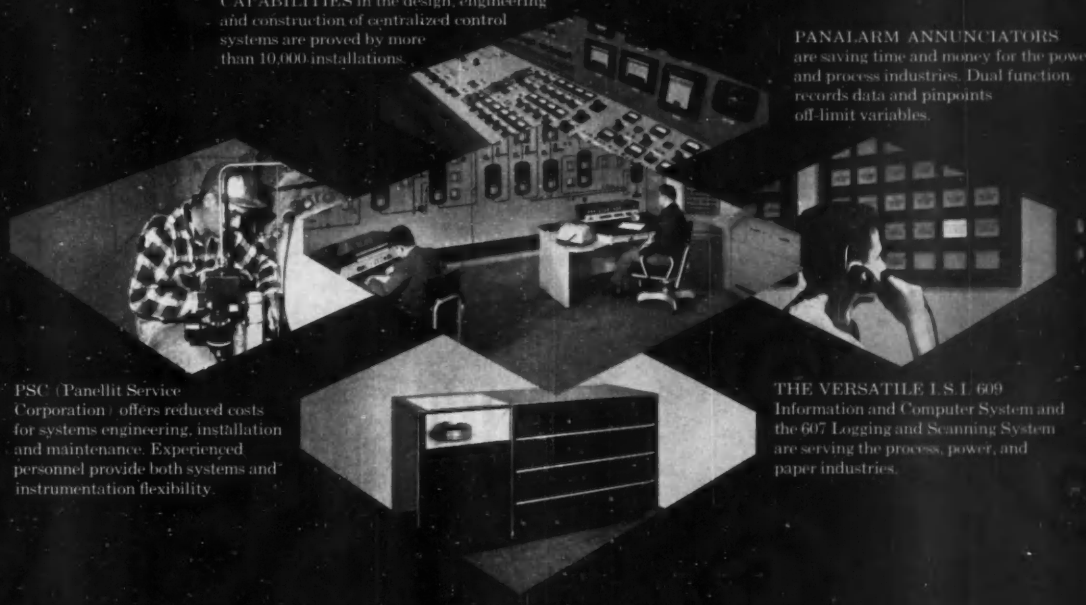

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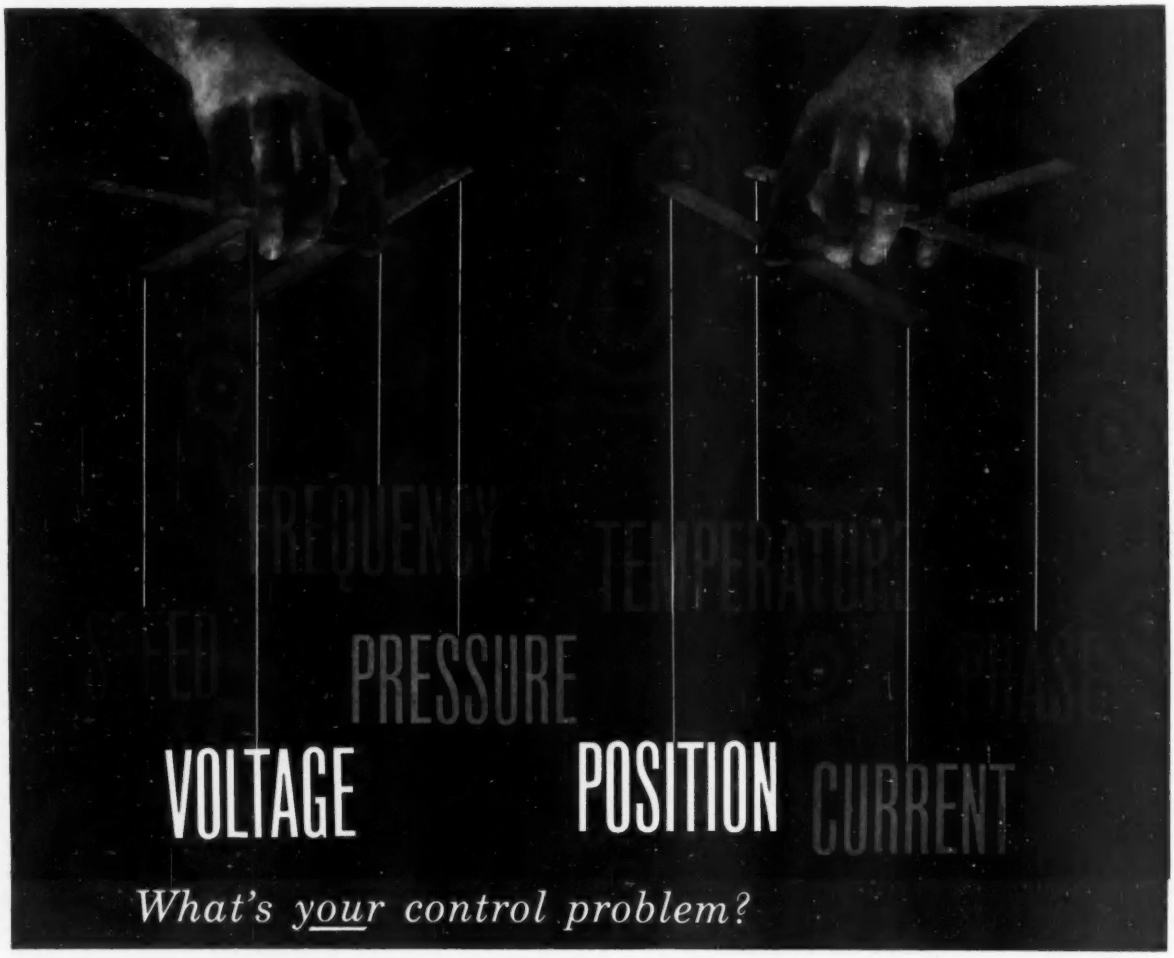

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Newsbreaks In Control

● Numerical Control Tackles New Fields

Los Angeles—Numerical control, nominally associated with machine tools, is slowly branching out. An LA control company is building a tape controlled system to mechanize sand slinging machines in foundries. Numerical control will speed up the operation and standardize quality. The sand slinger compacts sand for casting molds by slinging balls of sand into the mold at high rates of up to 3,000 lbs per min.

● Indiana Standard Convinced by Closed Loop Computing-Control

Whiting, Ind.—Standard Oil Co. of Indiana, which has been experimenting with both open- and closed-loop computing-control (CtE, Newsbreaks, Oct. '59, p 23), has been convinced that closed-loop control offers better economic possibilities. Standard will now build a facility to house its experimental instrumentation, with IBM computing equipment, for regular operation of a crude distillation unit. Standard's top executives claim their company "has as much know-how in this area as anyone including Texaco" (which over a year ago installed an RW-300 at its Port Arthur Refinery).

● New Census of Manufactures Figures Ready

Washington—Advance information on the 1958 Census of Manufactures is now coming out of the Bureau of Census, U. S. Dept. of Commerce. The once-every-four-year census of manufacturing indicates that the scientific instruments industry (SIC 3811) has made some giant strides since the 1954 census. Typical growth: number of employees up 40 percent, annual payroll has grown by 75 percent, annual shipments are up 57 percent.

● Teaching Machine Boom

Minneapolis—A boom in teaching machines, devices that will automatically instruct students in a variety of subjects, may start within the year. Informed sources say Minneapolis-Honeywell will be the next big company to announce plans to market a commercial machine. Already in the market: U. S. Industries, Rheem Mfg. Co., and General Atronics.

● Soviets Plan Program Control Boost

Moscow—Leningrad Economic Council has organized a new Program Control Dept. at the U.S.S.R. Technological Designing Institute to equip turret lathes, lathes, milling machines, and drill presses with program control. Hundreds of machines will be retrofitted with the new controls, and the number may run to thousands before the project is completed.

● U. S. Steel Eyes Giant Numerical Control Machine

Pittsburgh—U. S. Steel is considering the purchase of a specially designed tape controlled machine that will drill and cut to size structural steel for construction. The machine, which would be over 300 ft in length, is still in the proposal stage.

Langley's Tunnels Play Second Fiddle To Space Age

Wind tunnels used to be the prime activity at the Langley Research Center. But today some exciting space age control projects are taking precedence.

HAMPTON, VA.—

An automatic control system to kill the precessional motion of spin-stabilized space vehicles, techniques to measure the high temperatures of plasmas in magnetoplasmadynamic devices, and a centralized data center to gather at high speed the voluminous data generated in newly built hypersonic wind tunnels—these are samples of the new emphasis on space technology at the Langley Research Center of the National Aeronautics and Space Administration.

Until October 1, 1958 when the Langley Aeronautical Laboratory of the National Advisory Committee for Aeronautics became the Langley Research Center of NASA, the 710-acre facility's prime concern was producing data, mainly from wind tunnels, for the design and development of aircraft of all types. The Instrument Research Div. was a support organization whose job was to keep abreast of developments in measurement and to supply the users of Langley's 30 major wind tunnels with instrumentation service. Today, as the organization chart shows, IRD has branched out into new areas of both applied and basic research. And activity is no longer limited to measurement alone.

• **Spinning ball**—A good example of what's happening is the work of the Navigations and Communications Branch of IRD with an air bearing simulator (photo at right). Engineers of the recently enlarged Automatic Controls Section consider this simulator as basic to space vehicle control as the wind tunnel is to aircraft.

Consisting of an 8-in. diameter steel ball floating on air, the simulator has rotational freedom of motion in all directions. When a platform or space vehicle mockup is mounted on the ball, engineers can study a variety of spatial conditions, ignoring such inherent earthbound restrictions as restoring force and friction.

As a starter in October 1958, Langley built a single axis simulator to study nonlinear on-off controls. The present unit was built in 1959 when the controls group needed a simulator on which to mount a space vehicle autopilot.

Applied to checkout the controls for the Little Joe vehicle which propelled a monkey into space last January, the concept scored its biggest success to date. Little Joe's autopilot and eight reaction jets operated by compressed air were mounted on the simulator (so that the whole rig weighed almost 1,500 lb) then run through the sequence of events from launching to end of control. Space scientists knew exactly how the controls would perform before Little Joe ever left its launching pad at Wallops Island, Va.

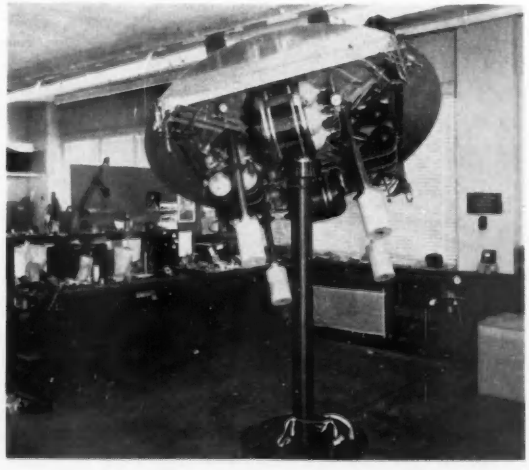
• **Nutational spin**—Next project for the simulator is to help in the development of an automatic control system to direct the last stage of space vehicles which are spin stabilized. Normally during the launching of a multistage satellite vehicle, an autopilot controls the first three stages. The last stage is then spun with the hope that it will continue moving in the same direction, just as a bullet is spun and directed by the rifling of a gun barrel.

Controlling a spinning vehicle introduces some sticky problems. For one thing the vehicle tends to act like a gyro so that forces have to be applied in a direction 90 deg from that in which the control is desired. Engineers hope to be able to do this with a single reaction control which is pulsed at just the right time.

To guide the final stage on a set trajectory, Langley is building a simple horizon scanner—a telescope with a light source. When the telescope sees land, a signal will be generated; when it sees space, no signal will be generated by the sensor.

In addition to preventing precession, the control has to correct errors resulting from "tip off", the separation of the spinning stage from the previous stage. As the earlier stage drops away, the spinning stage tends to change its direction as a reaction to the drop off.

• **Analysis and hardware**—While Langley is readying its air bearing simulator, other sections of the Navigation and Communications Branch have space project. One group, for example, is now testing the guidance system for an attitude control which Minneapolis-Honeywell has built for the Scout, an experimental vehicle. Another is performing systems analysis of a tracking system, to analyze the errors caused by station placement in a four-station Doppler system. And still others are doing computation work: for Project Mercury, the man in space project, to compute orbits; for Shot Put, a project in which a 100-ft balloon is fired from a rocket,



Air bearing simulator. Bottom view of platform shows air tanks which supply reaction jets. Controls are mounted topside.

to determine the proper time of launching to keep the balloon in sunlight a maximum amount of time.

• **What comes first**—Such activity requires a major shift in philosophy as well as interest. It means a complete reversal, says H. B. Edwards, assistant chief of IRD. "We used to do things manually first, then make them automatic. But with space projects, we have to do things automatically, later we may be able to send a man up and have him make measurements. In our former ground facilities work, for example, we were always concerned first with making the measurement correctly; an automatic system would come later when we were sure it did not affect the quality of the measurement."

Even the ground facilities work is undergoing a major change today. Wind tunnels are still important, but they are producing data for space vehicle reentry rather than airframe design. To keep pace, IRD's heavily loaded Data Systems Branch is installing a centralized data gathering facilities, will soon have additional on-line computing for wind tunnel users.

First step is the installation of three Beckman 210 high speed data acquisition systems in the branch's new computer building. One was installed in February 1959, a second is just being installed, and the third will be ready by summer. The 210's will receive analog signals from the wind tunnels—thermocouple readings and pressure signals—digitize them, convert them to computer format, and then put them on magnetic tape ready for computation. Addition of the system cuts the time between tunnel test and finished computer data to one-sixth of what it was formerly.

When the three systems are installed, the Data Center will be able to handle up to 800,000 readings in 6 min (one reel of magnetic tape); it will handle 7,200 channels of information per sec.

Because of the design of the 210's—they use high input impedance amplifiers so there is no attenuation of the signal—Langley will bring low voltage thermocouple signals into the center *without amplification* over lines several thousand feet long. Signals as small as 25 millivolts can be transmitted this way with no loss in accuracy of measurement.

Signals from any of 10 specially connected tunnels come into a patchboard (one for each tunnel). By arrangement of the patchboards, any of the three 210's can handle data from any of 10 tunnels. A changeover, gathering data from a different tunnel, can be accomplished in minutes if the center has been warned that the new tunnel will be ready to transmit data. If the tunnel requests use of the data acquisition system without having given previous warning, the center takes about 30 min to get ready.

• **Real time computing**—By June the center will be able to offer tunnel users one other service: real time computation. Engineers of the Data Systems Branch say the technique will supply aerodynamicists with test results as the test proceeds so that the testers can change environmental variables during the test instead of waiting hours or days for the results.

The key intermediate equipment, being built by Electronic Associates, will receive the output of existing analog-to-digital converters, put them into computer format, and transmit them to the IBM 650 computer for processing. Results will move from the computer to a variety of output devices like plotters and automatic typewriters near the tunnel. The system will be able to read up to 160 pieces of information, four characters per piece of information.

• **Measurement differs**—High speed data acquisition has been dictated primarily by the decrease in time of tunnel tests as Langley has started using hypersonic (Mach 25 speeds) and hot shot tunnels, in which a test may take only milliseconds. The change in data processing techniques is no more severe, however, than the change that has been forced on the measurement specialists.

In subsonic tunnels, models used to be supported by tripods; forces were "weighed" by beam balances. In supersonic tunnels, however, any strut in the line of the model changes the characteristics of the tunnel so that models have to be mounted from the back of the tunnel. Force measurements are now made by strain gage balances. And the increasing speed has dictated a need for smaller and better strain gages.

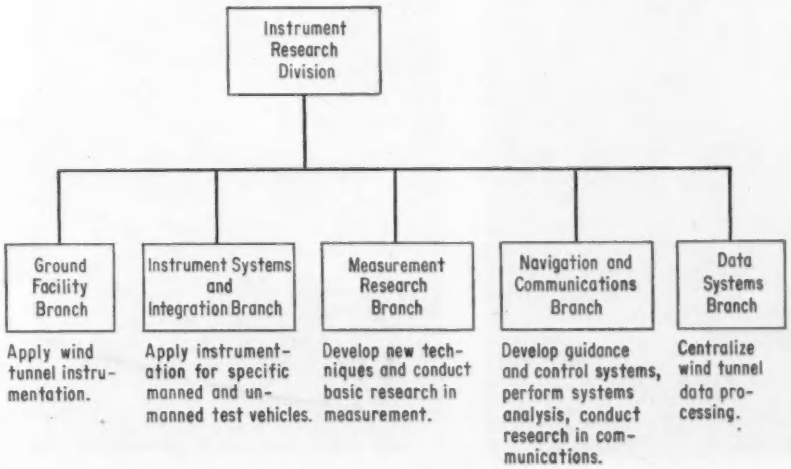
The high speed tunnels are running with low density atmospheres—necessitating more sensitive pressure devices—and high ambient temperatures—requiring new thermocouple technology and water-cooled balances. Shock tubes which also operate only for milliseconds force a whole new look at temperature measuring techniques.

• **Magnetoplasmadynamics** – How one measures such high temperatures is one of the projects in the Measurement Research Branch, which now is conducting some basic studies. What develops from this work may be used in another area of interest at Langley: megnetoplasmadynamics – high temperature ionized gases being used as power sources.

One technique new to Langley Field for temperature measurement is spectroscopy. Langley engineers are trying to measure temperatures of plasma with the same methods used by astronomers and physicists to determine the temperature of stars. The spectroscope supplies an average temperature, but it cannot yet provide a temperature gradient. Measurement is complicated by contamination of the gas stream; dust and carbon particles tend to hide the bands that are essential for temperature indication.

The switch to new techniques at Langley has affected practically all of the current staff of 3,400 (of which about 1,100 are professional people). Over 10 percent of the total budget goes for measurement and control activity. Almost 400 people are at work on instrument studies (half of which are engineers or scientists). And IRD buys over $1.5 million worth of equipment a year for its work.

—Lewis H. Young



A User Reports: Rapid Return from Tape Control

LAKE SUCCESS, N. Y.—The three tape controlled machine tools now spotted about the machine shop of Sperry Gyroscope Co.'s Air Arm Div. are expecting company. The equipment installed so far has shown such a spectacular and rapid economic return that plans are being rushed to greatly expand the numerical control content of the shop.

Last month CtE queried Stan Mihanovich, the man in charge of methods and tool engineering at the Air Arm Div., about his experience with numerical control. Mihanovich's replies constituted an enthusiastic endorsement, including some remarkable highlights:

- operating economies paid off one $20,000 control system in less than four months.
- servicing has been no problem—even with machines running on a two-shift basis.
- every new part is programmed for a tape machine, even when the machines are too busy to handle it.

In many circles Sperry Gyroscope is regarded as an "electronics company" relying on soldering irons rather than machine tools for producing goods. But a visitor to the vast Lake Success plant—big enough to serve as temporary headquarters for the United Nations just after World War II—soon comes to an opposite view.

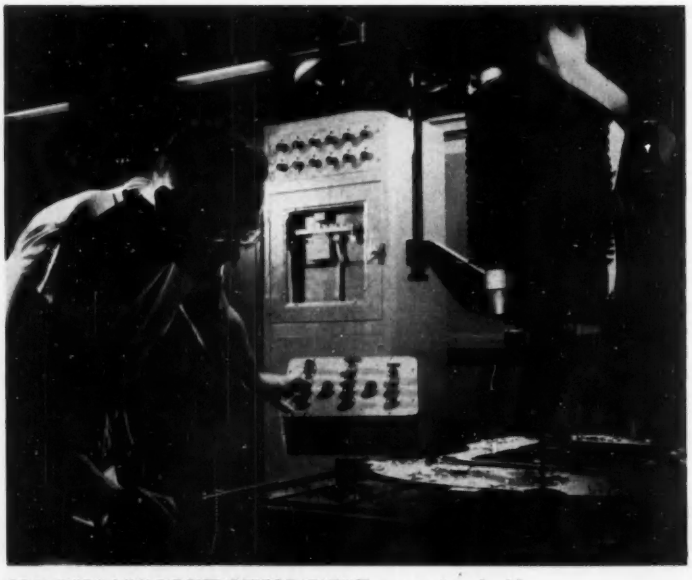
There, a 1 million-sq ft shop houses hundreds of machine tools—including batteries of drill presses and jig borers, which are inherently suitable for tape positioning control. Their heavy concentration on metalworking processes, plus the fact that production runs of parts for aircraft armament are normally in the range of 1 to 25 units, imbued Sperry engineers with an interest in numerical control techniques as far back as 1955.

• **In the family**—Despite this interest and persistent study of tape concepts, no hardware purchases were authorized until recently. Among the reasons for the delay: a couple of business dips and some dissatisfaction with the quality of controls available at the time. Then Sperry's Canadian affiliate began to market a numerical positioning system and the Lake Success operation rushed to buy.

The three working machines are a new Burgmaster turret drill, a retrofitted Bullard spacer table, and a DeVlieg Jigmil, also retrofitted. The Burgmaster proved the easiest to justify economically, delivered a documented saving of $2,427.80 in its first 77 hours of operation on 9 or 10 different parts. This figure includes only the direct savings on labor ($241.80) and tooling ($2,186); no values were assigned to coincident benefits such as reduced inspection time, more output per machine, increased tool life, and less storage space for jigs.

While the Burgmaster records far surpassed original estimates, the other two machines are proving out closer to predictions. In the case of the Bullard table, the methods people put the figure at $22,500 over a year of two-shift production. This embraces $17,000 just for the time saved in setting stops.

The original table also featured a



OLD BULLARD POSITIONING TABLE *was equipped with two-axis tape controls at total cost of $18,000. Controls are expected to pay for themselves within nine months of operation.*

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type of automatic positioning, but limit-switch trip dogs had to be set whenever the machine was changed for a new part. There were as many as 31 stops; setup time was 8 min per stop. Tape control eliminates setup time entirely, while providing an unlimited number of stops. The elimination of one 5-sec dial change required for the original table alone will be translated into a $1,000 cost advantage over the year.

• **Everything's on tape**—Unquestionably the most convincing tribute to the new controls is that the methods group now prepares a tape for every new part design emerging from the engineering department. This is true despite the fact that the three machines cannot begin to handle the total flow. Although a part may have to be turned out on a conventional machine at first, a numerically controlled machine may be available for the second run.

Sperry's methods group has taken the need for parts programming in stride. No additional personnel were required, and retraining efforts have been moderate. Clerical typists turn out punched tapes on Friden equipment on the basis of standardized worksheets filled in earlier by detailers. No attempt has yet been made to "sell" engineering and drafting groups on coordinate dimensioning.

• **Two in seven months**—The maintenance department, too, has found that the tape machines have created no particular problems. In seven months of operation, only two calls for help were made to the Canadian plant. Local service people handled all other breakdowns, although they were not given any special training except for that gleaned from Canadian technicians during the installation and shakedown phases.

However, Sperry people admit that their maintenance groups are heavily populated with "electronic electricians" who are accustomed to servicing complex electronic gear.

Sperry management, noting the quick return on the first three systems, is about to enter on a numerical control buying spree. The fourth machine – another Bullard retrofit – is nearing completion. The initial four will be joined within the next year by between four and eight additional units, both new and retrofitted.

And, some enthusiasts in the division predict that within five years, over 90 percent of all drilling and boring operations will be performed on tape controlled machines.

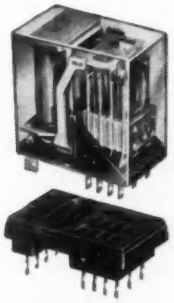
—John D. Cooney

ALLIED CONTROL'S

NEW LINE OF

Sub-Miniature Telephone Type Relays

Now being manufactured entirely in the U.S.A., not only in its original West German design previously sold in this country by Allied Control Company, Inc. under an agreement with Siemens & Halske Company A.G. Germany but with variations to meet American requirements as well.

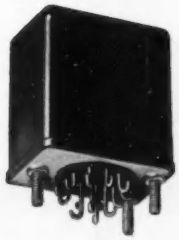


TYPE-T-154

H- 1 3/16 • W- 47/64 • L- 1 11/64

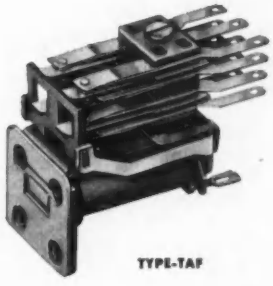
TYPE-TAHG

H- 2 3/16 • W- 1 7/16 • L- 1 5/8



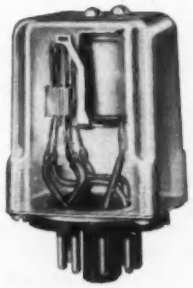
TYPE-TAH

H- 1 19/32 • W- 61/64 • L- 1 11/32



TYPE-TAF

H- 1 17/64 • W- 41/64 • L- 1 5/16



TYPE-TADO

H- 2 • W- 1 13/32 • L- 1 13/32

PERFORMANCE CHARACTERISTICS

Contact Arrangement
Up to 12 springs maximum form A, B or C

Contact Rating
2 amperes resistive or 1 ampere inductive at 29 volts d-c or 115 volts a-c
Low level or 5 ampere contacts available on request

Standard Coil Voltages
Suitable coil resistances can be supplied for operation at any voltage within the range of 0.5 to 130 volts d-c

Coil Power
Nominal: 700 milliwatts
Minimum Operate Power: 125 to 300 milliwatts depending on application, contact arrangement and coil resistance.

Timing at Nominal Voltage
Operate time: 15 milliseconds maximum
Release time: 5.0 milliseconds maximum

Vibration
10-55 cps at .062 inch double amplitude
55-500 cps at a constant 10g

Shock: 25g operational

Enclosure
Open, dust cover or hermetically sealed

Weight
Open type 1.0 ounce maximum
Sealed type 2.0 ounces maximum

ALLIED CONTROL

ALLIED CONTROL COMPANY, INC., 2 EAST END AVENUE, NEW YORK 21, NEW YORK

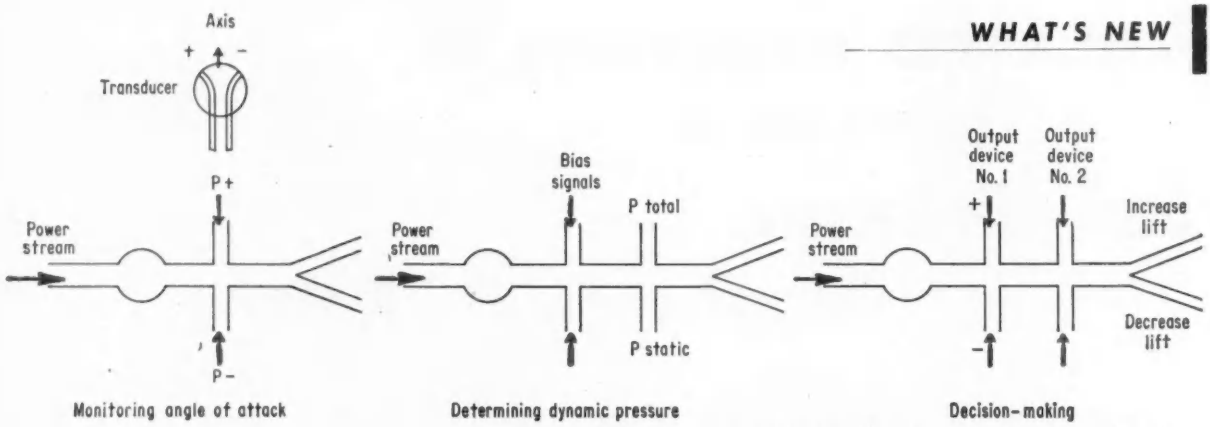


FIG. 3. How pneumatic computing elements might perform in a simple one dimensional aircraft control (description on page 28).

Fluid Computing Elements Open New Doors in Control

Diamond Ordnance Fuze Laboratories calls its new device a fluid amplifier. You can add, subtract, multiply by combining the devices. And it is possible to build a variety of functional and logic devices such as AND and OR units, oscillators, flip-flops, and reaction controls.

WASHINGTON—

A fluid power stream is modulated by two or more fluid control streams positioned opposite to each other and at right angles to the power stream—that is how a radically new amplifying device works (Newsbreaks, CtE, Dec. '59, p. 21). Called a fluid amplifier by its developers, three engineers (Dr. R. E. Bowles, B. M. Horton, R. W. Warren) at the U. S. Army Ordnance Corps' Diamond Ordnance Fuze Laboratories, the new device appears to have widespread military and industrial applications. At DOFL, engineers say that the operation is based on some well known laws of fluid mechanics and some not so well known behavior of boundary layers.

On the surface the device looks disarmingly simple. It has no moving parts. Figure 1, for example, shows how a fluid amplifier might work as a digital device. The control stream directs the power stream into the proper output passage. Operating control streams have worked successfully at very low pressures, as low as 10 in. of Hg vacuum.

Figure 2 shows how DOFL engineers help deflect the power stream with the low pressure between the sidewall of the device and the power stream. This permits a very low pressure to serve as the control pressure. Sidewall pressure distribution also permits the application of feedback without a special channel in the device. If feedback paths from the output apertures are made to two additional control nozzles, the modified device has a memory capability, can "lock" the power stream in one path or another. To date DOFL engineers have been able to build amplifiers with a power gain of as much as 100.

The same approach can be harnessed to produce an analog device with the power stream being modulated by a low energy control signal so that the output stream has a related energy flow at a higher energy level. The control streams direct only a proportional amount of the power stream into the desired output opening, and the output can be determined either by mass flow, velocity, or pressure of the stream.

By judicious application, the fluid amplifier has performed a variety of functions. They have served as AND or OR logic units and as binary stages

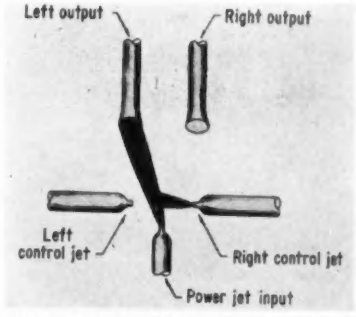


FIG. 1. Fluid amplifier as a digital device.

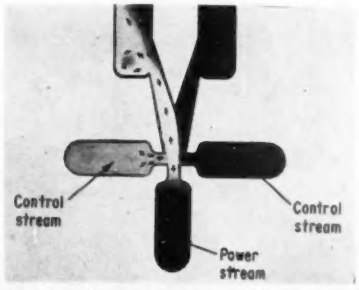
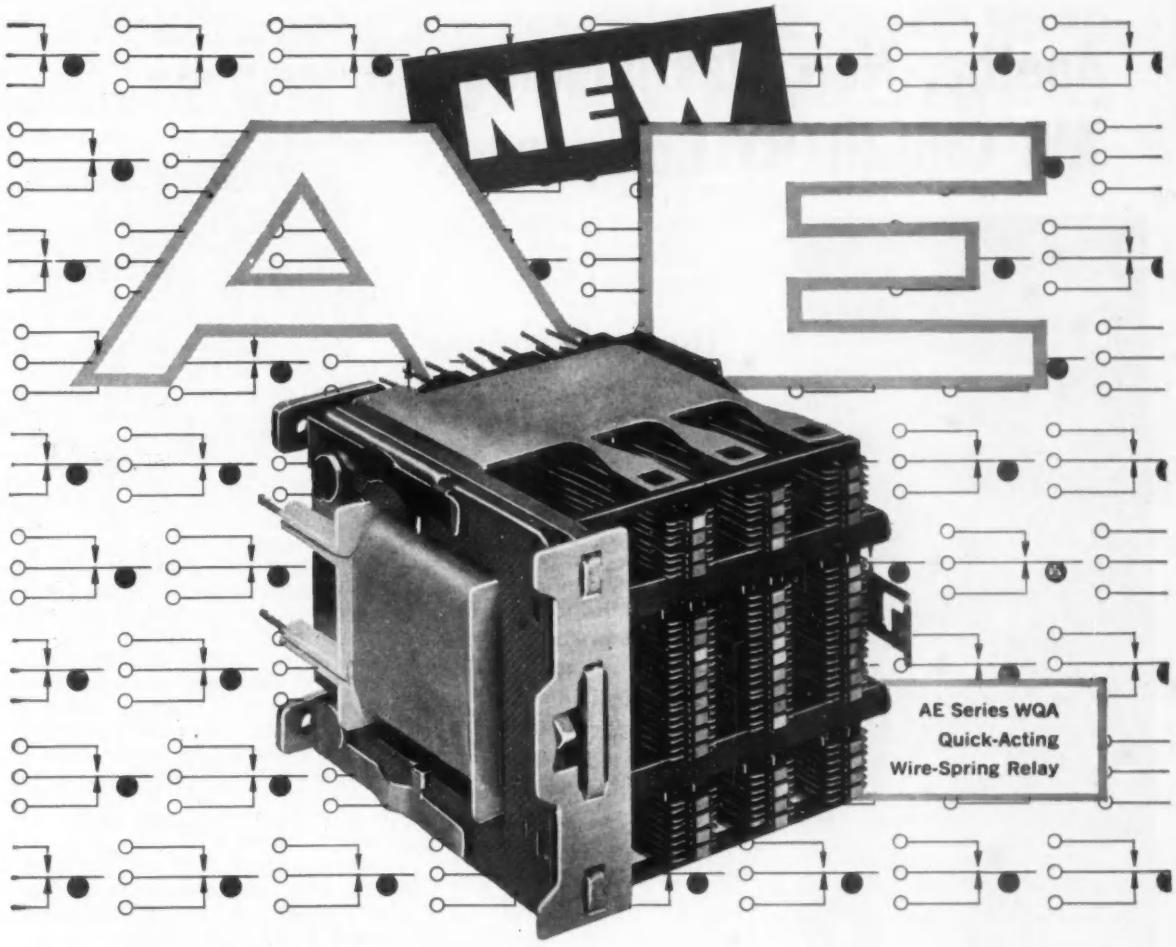


FIG. 2. How pressure helps direct power stream so unit will operate with very low pressure control streams.



TO THE ENGINEER

who wants to transfer 51 circuits simultaneously

If you need simultaneous transfer of a large number of circuits without fail, take a look at AE's new WQA relay. It will do the work of four or more heavy-duty, general-purpose relays each with maximum spring pile-ups, and sustain 50 million or more operations without readjustment.

In the WQA relay, all moving springs pass through holes in a unique actuating "card." Moved directly by the armature, the card in turn actuates all the moving springs. This method of operation pre-establishes exact timing and sequence of all spring operations, and at the same time assures perfectly synchronized "break-before-make" on all circuits.

Contact capacities on WQA relays can be custom-tailored to your needs, with either one, two or three levels of contact assemblies available, each with a capacity of 17 Form C combinations. Other Forms available.

Our circuit engineers will be pleased to work with you in adapting the WQA to your specific design. Or, if you wish, they'll take on the complete packaging job.

If you'd like more information on the WQA relay, address your request for Circular 1957 to: Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois.

AUTOMATIC ELECTRIC

Subsidiary of

GENERAL TELEPHONE & ELECTRONICS

WHAT'S NEW

of a scaler. If units are combined, the fluid amplifiers can add, subtract, or multiply either as analog or digital systems. If a feedback path is connected to the input, an oscillator is produced. In this way DOFL engineers have been able to build extremely low frequency fluid oscillators, as low as 6 cycles per min., and as high as 10 Kc.

• **An aircraft example**—Nobody has yet marketed a control system using the fluid amplifying devices. But here's how a simple one dimensional analog aircraft control might work. If the fundamental control equation were

$q = \frac{1}{2} \rho v^2$
q = dynamic pressure
ρ = density
v = velocity

then dynamic pressure is a function of velocity and density. If an intake opening is placed at an angle with direction of flow of air, then the pressure in this pickup is a function of angle of attack and velocity so that measurements of pressure are the only inputs required to measure angle of attack of aircraft. In this simple control, three fluid amplifiers might be used:

1) One would monitor the angle of attack. The control streams of the fluid amplifier would represent pressure measurements at equal positive and negative angles with respect to the centerline of movement. The output controlled by this pressure difference serves as an input to the third amplifier.

2) Fluid amplifier number two would compute dynamic pressure, which is the result of subtracting static pressure from total pressure (as measured in a pitot tube). Total pressure would serve as one control stream, static pressure as the other, the difference directing the input power stream. Output of this second device then serves as another of the control streams of the third fluid amplifier.

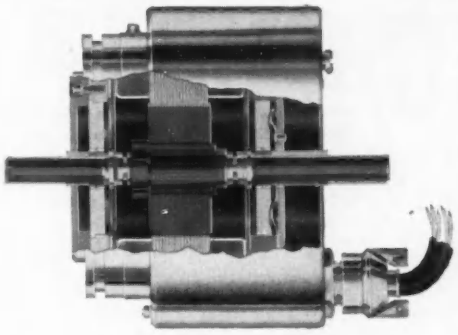
3) The third amplifier would then make the control system decision comparing what was being done to what should be done—increasing or decreasing lift.

Output of the third unit might then be converted from a pneumatic to a hydraulic signal to operate the actuators.

• **Reaction controls**—The units already built—oscillators, bistable units, flip-flops, memory units, and tristable units—promise some intriguing applications. For example, the tristable unit appears to have a number of special advantages as a reaction control for a missile or space vehicle.

With a low pressure input stream,

NOW ultra-accuracy possible in 2-speed servo systems with use of Ketay Vernier Resolvers



Ketay has developed a Vernier Resolver which permits the Systems Engineer to achieve utmost accuracy in his two-speed system. Replacing the fine speed transmitter and associated gearing on one end, and the fine speed receiver with coarse-to-fine gearing on the other end, it provides a basic system accuracy from input to output shaft of the order of 20 seconds of arc, maximum.

Operating on a variable reluctance principle, this resolver accomplishes its gear-up electrically . . . permitting coarse and fine speed units to be coupled directly. Thus, costly gearing with its contributing errors is eliminated. Also, as a variable reluctance device, it requires no windings on the rotor and therefore no sliprings or brushes. Errors due to brush contact resistance are eliminated, while greater reliability, extremely low breakaway torque and longer life are achieved.

The Vernier Resolver, in conjunction with a standard resolver, may also be used as a highly precise shaft angle encoder.

TYPICAL SPECIFICATIONS

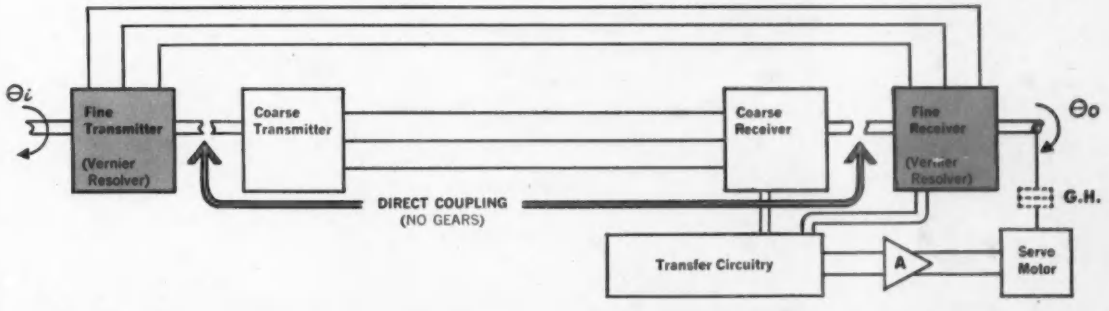
These typical specifications are for a particular vernier resolver designed for a specific application and are included here to give a general idea of what parameters are available. Vernier resolvers can be supplied for a wide range of voltages, currents and frequencies. Electrical to mechanical ratios can be changed to suit specific needs.

	Type #	SP.164
	Electrical to Mechanical Ratio (Gear up)	64 : 1
	Excitation	10 volts, 2.441 K.C.
	Error Spread of Null Crossover points (Max.)	12 (seconds)
(3), (2)	Error Spread over a Vernier interval (Max.)	4.5 (minutes)
	Maximum over-lapping error between intervals—approx.:	21 (seconds)
	Peak Output Voltage: (volts)	2.3 ± 10%
	Peak Output Voltage on reference winding: (volts)	2.5 ± 4%
	Open Circuit excitation current (untuned) (amps)	0.64 ± 4%
	Open Circuit excitation current (tuned) (amps)	0.065 ± 10%
	Open Circuit power (watts)	0.65 ± 10%
	Max. Starting Torque (in-oz.)	0.1
	Input impedance (ohms)	15.6 ± 4% /84°
	Null Voltage at Zero Points: (total rms)	7.5 mv.
	Peak Third (3) harmonic voltage (mv.)	8.5
	Phase Shift of output to input, approx.	3°
	Ambient temperature (C)	−20° to + 70°
	Weight—approximately	8 lbs. 13 oz.

NOTES:
1. Configurations, size, weight, etc. can be modified to suit specific applications.
2. Error spread can be trimmed down to value of over-lapping error or less.
3. Error is for unit being used as 2 Phase Transducer.

Submit your problems to us and a qualified Ketay engineer will show you how a vernier resolver may solve them.

USE OF VERNIER RESOLVER IN TWO SPEED SYSTEM



KETAY DEPARTMENT

NORDEN
DIVISION OF UNITED AIRCRAFT CORPORATION
Commack, Long Island, New York

WHAT'S NEW

the device is bistable. But when the input stream's pressure is sufficiently high, the fluid amplifier becomes tristable. Under such conditions a device would not only serve as the actual reaction jet of a missile, but it would also be part of the computer to determine how much force to emit and at what direction to aim the jet.

• **Appear inexpensive**—For demonstration purposes, DOFL has built fluid amplifying devices as big as 4 in. square and as small as a shirt button. They have drilled the passages for the fluid streams in metal blocks and in ceramic discs (for high temperature application). At this state of the art, DOFL thinks the devices will be inexpensive. And their reliability is high because of the absence of any moving parts.

Response times of the devices are, of course, much slower than electronic units, but are faster than conventional pneumatic or hydraulic elements. Current work at DOFL is to obtain more fundamental design characteristics about the devices.

One of the most intriguing possibilities for using fluid amplifiers lies in the process control field. It may be possible to compute, perform logic functions, and control a process stream using the process fluid itself as a source of power.

Design Conference in May

For the first time since it was started several years back, the ASME annual design engineering conference will be held in New York at the Coliseum. Along with a 400 exhibit design show, the four-day meeting (May 23-26) will offer at least five sessions of prime interest to control engineers:

Tuesday	Reliability
Tuesday	Hydraulics
Wednesday	Control Systems
Wednesday	Automation
Thursday	Computers in Design

The reliability session will consider "Reliability Prediction as a Design Tool" and "Impact of Reliability on Design".

Two papers will be heard in the control systems session: "Analysis of Control Systems by Analog Computer" and "Computers in Control".

The use of computers in design will be discussed by a panel of users who will consider the types of problems to solve on a computer and which computer to use; training of personnel; costs of installation and operation.

LIFEGUARD STATION

for a man in space

The vital Cape Canaveral nerve center for Project Mercury, the U.S. program to put a man in space, is being designed and built by Stromberg-Carlson-San Diego. Display information about the flight will be fed to the operations room from computers and from a world-wide network of tracking and telemetry stations. One wall of the 40 by 60 ft. operations room will be a large map display, visually summarizing all pertinent information about the flight. It will show the capsule moving along its orbital flight path around the earth and will also show the location, range and status of all ground based equipment and communications links. The operations room will contain display consoles presenting information to the Flight Director, Chief Flight Surgeon, Capsule Communicator, Flight Dynamics Officer and other decision-making personnel. For information on how Stromberg-Carlson-San Diego can help solve your data/display problems, write to Department A-48, 1895 Hancock Street, San Diego 12, Calif. Telephone CYpress 8-8331.

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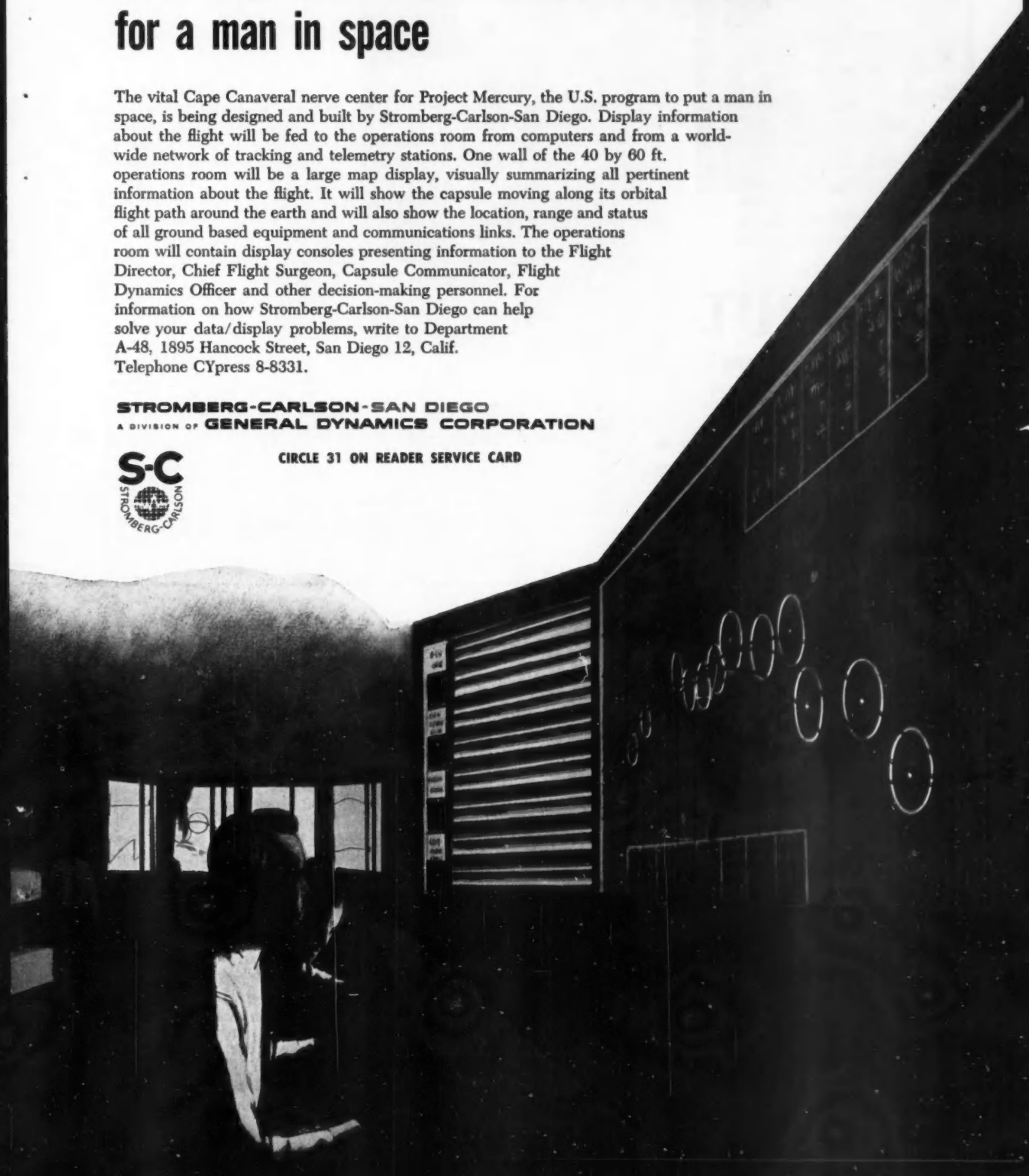
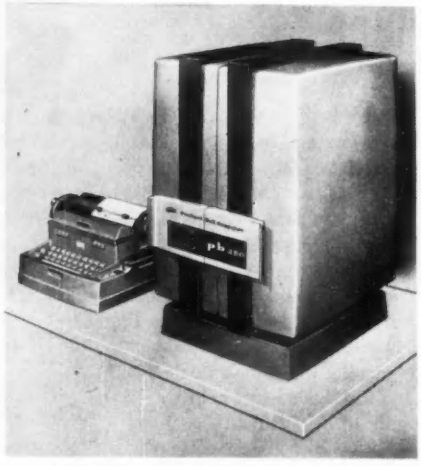
A DIVISION OF **GENERAL DYNAMICS CORPORATION**

S-C STROMBERG-CARLSON

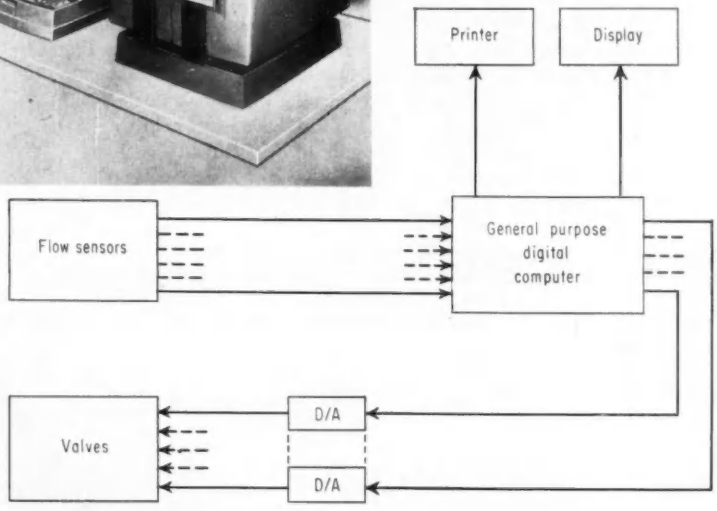
CIRCLE 31 ON READER SERVICE CARD



GP Computer Designed As a System Component



Artist's conception of the new Packard-Bell computer (at left) with a block diagram showing how it might be used in a control application.



LOS ANGELES—

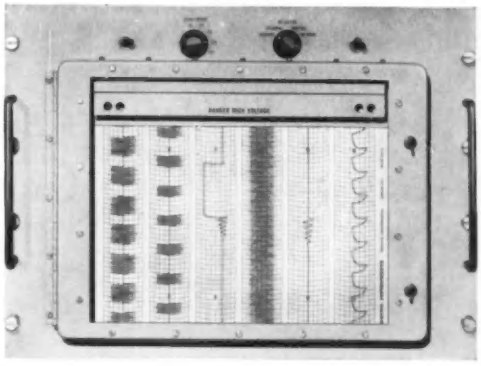
The general purpose electronic digital computer is rapidly moving out of the category of an office machine, a centerpiece designed to solve engineering, scientific, and/or business data problems. Computers have already been installed or planned to control chemical processes, as part of automatic inspection operations, and to direct steel mill machinery. Last month another computer milestone was reached: Packard Bell Computer Corp. unveiled a machine designed solely as a systems component to be used in a variety of military and industrial applications.

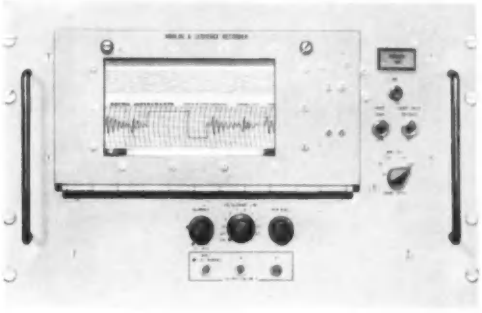
The artist's conception of the machine shows relative size. It was designed to fit a standard electronic equipment rack, requiring 31¼ in. of a standard 19 in. wide rack.

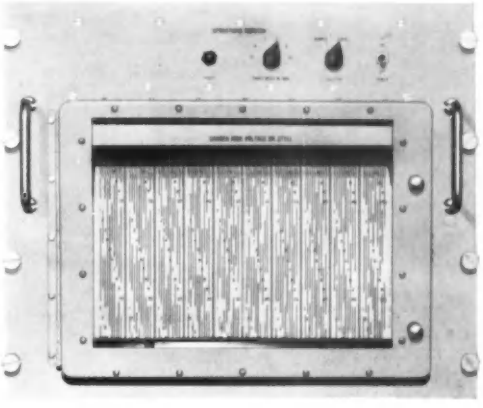
• **High speed**—To perform its function as a systems component, the new PB250 machine has some interesting design features. For example, it is fast. The solid state machine has an add time of 12 microsec, a multiply-time of 276 microsec, and a division and square root time of 252 microsec. Floating point operations require less than 3 millisec.

At first glance, says Packard Bell Vice-President Max Palevsky, the speed looks excessive because most applications do not require such rapid arithmetic operations. But the speed permits the machine to be time-shared among a number of operations. For example, in an application such as indicated in the figure above, the computer may have to perform many computations for each variable from the sensors or to determine each valve setting. If there are even a moderately large number of sensors or valves, says Palevsky, a very fast machine is re-

CIRCLE 33 ON READER SERVICE CARD→







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Brush equipment is already at work putting evaluation data in writing for a whole new generation of weapons. When the weapons become operational, Brush MIL Recorders are a vital part of the system. This experience is unique in the industry. *Before* prototype design becomes a problem—call, write or wire Brush for complete details.

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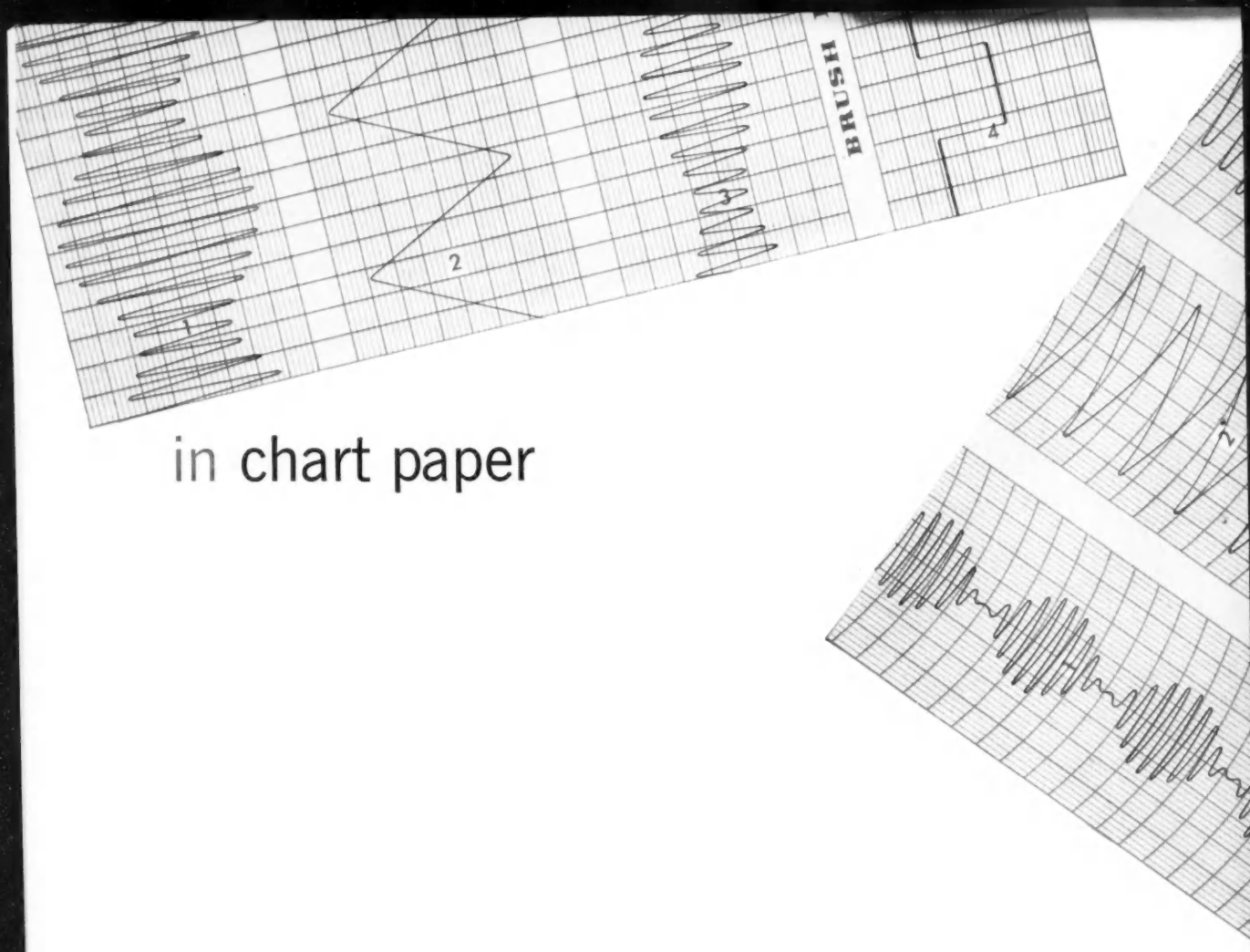

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Only Brush Chart Paper is designed as an integral component of precisely engineered Brush Direct Writing Recording Systems. The full potential of these systems cannot be realized unless *all* of the original components are utilized. They're engineered as a *total* entity. Imitation papers cannot match the precision ruling, dimensional stability and super-smoothness of Brush Chart Paper. Take no chances—specify *Brush* and you can rely on your records being accurate, permanent, easily read and easily reproduced. Stocks available from strategically located branches and sales representatives throughout the United States and Canada.

Write for samples of actual tracings on Brush Chart Paper. Ask for "Check the Record".

quired to handle them.

Another unusual design feature is the memory. Packard Bell uses magnetostrictive lines mounted on plug-in modules for internal memory. The basic memory capacity is 1,808 words (with a 22-bit word) and is expandable to 15,888 words. In addition, an external magnetic core memory can store up to 16,384 words.

• **Input-output**—The PB250 has three independent input-output schemes. One, character input-output, operates on characters of up to eight bits in parallel. It can be used to process information to and from a paper tape reader and punch of a Flexowriter and to and from a keyboard. A high speed paper tape reader and magnetic tape units are available. The machine can use up to six magnetic tape units employing standard IBM 700 series format.

A second method of input-output permits information to be entered and taken out of the computer serially at very high speeds—a 2-megacycle bit rate. A stored format can place input information in any configuration within the memory, while the same format acts to select the desired information on output. This method is suited for punched card equipment, digital to analog converters, and high speed communication with other digital parts of the system.

The third scheme consists of 30 input and 32 output lines that control and are controlled by the program. The input lines can be individually tested to determine the presence or absence of a signal and the computer program modified on the basis of this test. In this way feedback signals, timing signals, and the state of various devices in other parts of a system may be sensed.

The computer can also place signals on any of the 32 output lines and, further, the duration of these signals can be accurately timed for from 12 microsec to 3 millisec. These signals can control the starting and stopping of various equipments, the sequencing of stepping switches or electronic commutators, and the overall synchronization of complex systems.

• **Small component count**—Another attractive feature of the PB250 is the cost—about $30,000. One reason for the relatively low cost is the small number of components in the machine, less than 350 transistors. The computer runs on only 30 watts of dc power, needs two voltages: minus 12 and plus 6 volts, so the computer can be powered by batteries.

WHAT'S NEW

Data on the Move

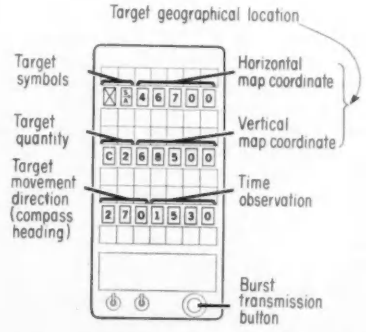
New methods for transmitting data are unveiled: a digital system with industrial applications and television over telephone long lines.

Next month at Quantico, Va., U.S Marines will start evaluation of a strange new weapon: a digital system for sending battlefront information from front line scouts to battlefield commanders. Called BASIC, for Battle Area Surveillance and Integrated Communications, the system was developed by Stromberg-Carlson Div. of General Dynamics Corp. at its San Diego Div.

It is one of several methods for the large scale transmission of data announced last month. Two others: International Telephone and Telegraph Corp. has built for the Air Research and Development Command a television system that can transmit maps, charts, and pictures over long telephone lines; Telectro Industries Corp. has built Telectrovision for an Air Force weather radar data project; it, too, can transmit photos or written data over long telephone lines.

Both the ITT and Telectro Systems transmit pictorial data on telephone long lines instead of coaxial cable. In the ITI system an audio telephone line can be used for a two-way conversation to discuss the pictorial transmission. In the Telectro system one user of the system can tie in with any other merely by dialing in. And the picture can be stored in an electronic tube and viewed on demand.

• **Getting BASIC**—Stromberg-Carlson's device is designed to be carried by scouts who would radio back specific information about targets,



Stromberg-Carlson has built a BASIC readout unit for the marines that looks like this.

HIGH POWER
IN SMALL PACKAGES

HIGH POWER
IN SMALL PACKAGES

HIGH POWER
IN SMALL PACKAGES

HIGH POWER
IN SMALL PACKAGES

HIGH POWER
IN SMALL PACKAGES

Unhampered by traditional thinking, TELECHROME engineers have developed an entirely new concept in telemetering equipment — unequalled in compactness, ruggedness and dependability.

TELEMETERING TRANSMITTERS FM/FM or PDM/FM Crystal Controlled 215 to 260 Megacycles

NEW! 1483A1 — 4 Watt FM Transmitter.

1⅝" x 2¾" x 4"
Features AFC for .005% stability

Model 1463 Transmitter.

$5\frac{1}{32}$" x $3\frac{13}{16}$" x 4"
15 to 30 Watts

Model 1460-M RF Amplifier

3.37" x 3.25" x 2"
2 Watt input; 10-30 Watt output

Model 1466A-AF Amplifier

6.5" x 4" x 3.25" RF Amplifier
2 watts in — 100 watts out

Model 1462 Transmitter.

6" x 4¼" x 3¾"
50 to 80 Watts

800C — Sub-Carrier Oscillator

1.9" x 1.9" x 2.45"
Dev. Stab: ± 1% band width
Dev. Linearity: Less than 1% band width

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WHAT'S NEW

their location, and movement. It consists of a digital message entry device, a Charactron tube display for visual readout, and an electric typewriter for a permanent record. The entry device plugs into any existing radio or communications system. Its transmission takes up so small a part of the band that voice transmission can be made at the same time.

Powered by batteries, the entry device sets up its information with three rows of seven switches, then puts out a serial type of transmission. Actual sending is performed in a single short burst. Information is displayed on the Charactron tube within 3 sec of its being sent.

Optically registered to the display face of the viewing tube is a standard military map. After target location symbols are positioned geographically on the map, alphanumeric characters and symbols appear to indicate type of target, position, target quantity, direction of movement, time of observation and identity of the observer. Up to 50 targets can be displayed on one map.

Stromberg-Carlson envisions a flock of industrial and commercial applications for BASIC. For example, banks might use the system to speed customer credit checks, and factories could use it with a computer for production control.

Temco Diversifies: Centralized Control for Coin Laundries

DALLAS—

Aircraft company diversification took another strange bounce last month. Temco Aircraft Corp.'s industrial division announced a central control system for coin-operated laundries. Incorporated into a single machine, the system makes change, stores collections, and activates a battery of laundry and drying machines.

The control system is divided into three separate circuits. Each circuit has its own coin receiver, can control up to 26 machines so that the central unit can handle up to 78 laundry machines. Each machine—washer or dryer—is connected to the central control by four wires.

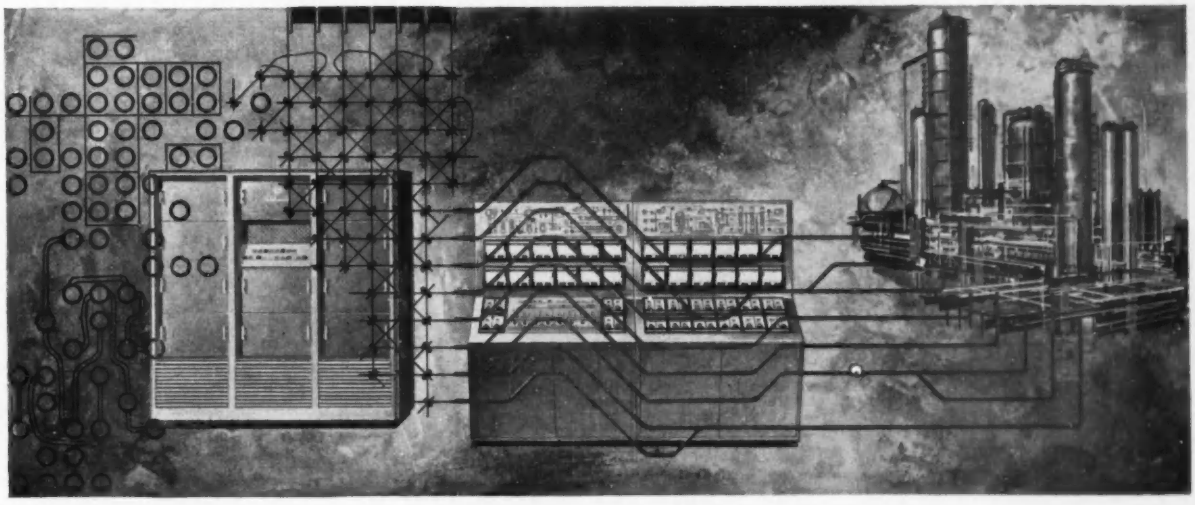
Here's how the system performs. After a customer has deposited the proper change into the central control machine and pushed the button corresponding to the machine being used, the central control counts the

the instruments

the computer

the systems engineering . . .

now Foxboro brings you all three



A dynamic new force in computing control is now available to the process industries. Foxboro, and the Radio Corporation of America, contributing their individual capabilities, bring industry its first completely integrated computing control system. From Foxboro, the instrumentation, the knowledge of process dynamics. From RCA, the digital computer, and its special electronic techniques. A breadth and depth of talent available with overall systems responsibility through The Foxboro Company. When you are investigating the feasibility of computing control, look into this new force. The Foxboro Company, 365 Norfolk Street, Foxboro, Massachusetts, U. S. A.

FOXBORO

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WHAT'S NEW

Temco's coin control.

coins, makes change if necessary, activates the machine, and starts it on its sequencing cycle.

One of the key parts of the control is the coin receiver, being supplied by National Rejectors, Inc. The receiver has a counter and five small miniature switches to energize the laundry machine and to make change. By flipping a switch the owner of the equipment can change the action of the counter to increase or decrease by a nickel the cost of using the machine.

One reason laundry operators have shown interest in the central control is that they feel it will cut down vandalism on the coin meters currently installed on each washer and dryer. Another advantage is that the central control incorporates change making capabilities so that the owner of a laundry does not need a separate change maker tying up $100 to $150 in change.

To make change the machine has a special tube into which move the first 60 nickels deposited by customers. Overflow after that and other coins move directly to a safe built into bottom of the central unit. The safe is divided into three compartments so that the owner can tell the business each battery of machines is doing.

Temco is now producing 250 of the new central control machines. The system is the first company developed commercial item since the Industrial Div. was formed several months ago.

—Marvin Reid
McGraw-Hill News

cppc OFFERS NEW DIMENSIONS in Pancake Synchros

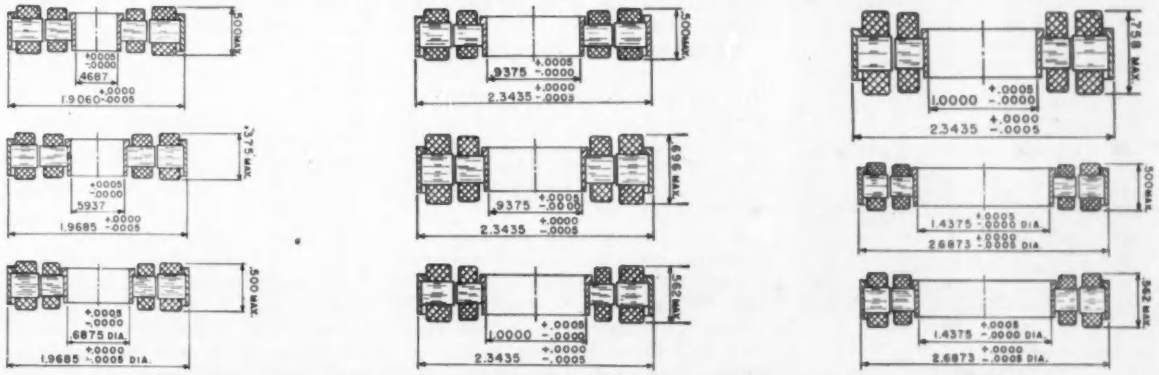
MOUNTING AND HOUSING DIMENSIONS TO ORDER. Here are a few typical configurations obtainable in aluminum, stainless steel, beryllium or zirconium alloys.

SIZE 23
Leads and terminals.

SIZE 28
Tandem unit. Transmitter and Resolver.

SIZE 37
Accuracy: ±4′ max. error.

A WIDE VARIETY OF BORES AND STACK HEIGHTS, widths and diameters available from existing laminations. Below are some examples. Let us know your needs.



ENGINEERS—Pioneer with a leader in the field. Write David D. Brown, Director of Personnel. Dept. A3.

cppc

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Will a Government Automation Center Break Britain's Information Bottleneck?

A top British control consultant claims slow progress in industrial controls over past five years is the result of poor information flow between maker and user. A proposed center may speed progress.

LONDON—

When first introduced to Britain at a conference back in 1955, the words "automation" and "control engineering" excited British industry, produced special supplements in the daily press, and started equipment makers hastily reorganizing in readiness for what they expected would be a flourishing field.

But five years and some extensive reorganization later, the hoped-for orders are not rolling in at the expected rate. Control equipment sellers find rough going as they try to crack traditional British conservatism.

Reasons given for the order famine range from diminished enthusiasm through lack of information feedback between user and maker to lack of graduate engineers in the production field (only 10 percent of British graduates take up production engineering).

• **A government center**—Leading solution coming out of industry now is the suggestion that a National Automation Center be set up as part of the government sponsored Dept. of Scientific and Industrial Research (DSIR). It would probably be located close to Britain's National Physical Laboratory.

Specialists in each of the automation fields would staff the center and would field incoming queries from industry. A permanent exhibit of typical applications in each field—with a breakdown of the economic advantages of controls—would be aimed at selling industry brass.

A second answer may come out of the recent move by Production Engineering Ltd., one of Britain's larger consulting firms, which is setting up a section for automatic inspection systems. Says David Nicolson, managing director, "we want to generate in the industry the same enthusiasm for automatic inspection as British industry now has for the currently fashionable diversification rage. Money spent on modernizing the existing methods can eliminate the need to diversify."

• **The scoreboard**—But just how much has been done in the past five years? CtE asked one of Britain's top control consultants, Dr. David Foster, for his verdict. According to his survey of 100 British firms, "Britain is strong in ideas, but user industry lags in their adoption. On the average it is two to five years behind the U. S."

Dr. Foster divided the field into 10 basic areas and summarized their position for CtE. Following each performance rating is a capsule rundown on the achievements to date.

▶ **Batch process sequencing and dispensing control—good progress**

This sector is forging ahead, especially in automatic dispensing of solids and liquid mixes according to punched card and tape recipes. Wide acceptance of these technques is largely due to adoption of simple telephone techniques involving stepping switches in standard functional units. The second phase—solid state actuator monitoring systems—is now being introduced.

▶ **Computer controlled processes—still exploratory**

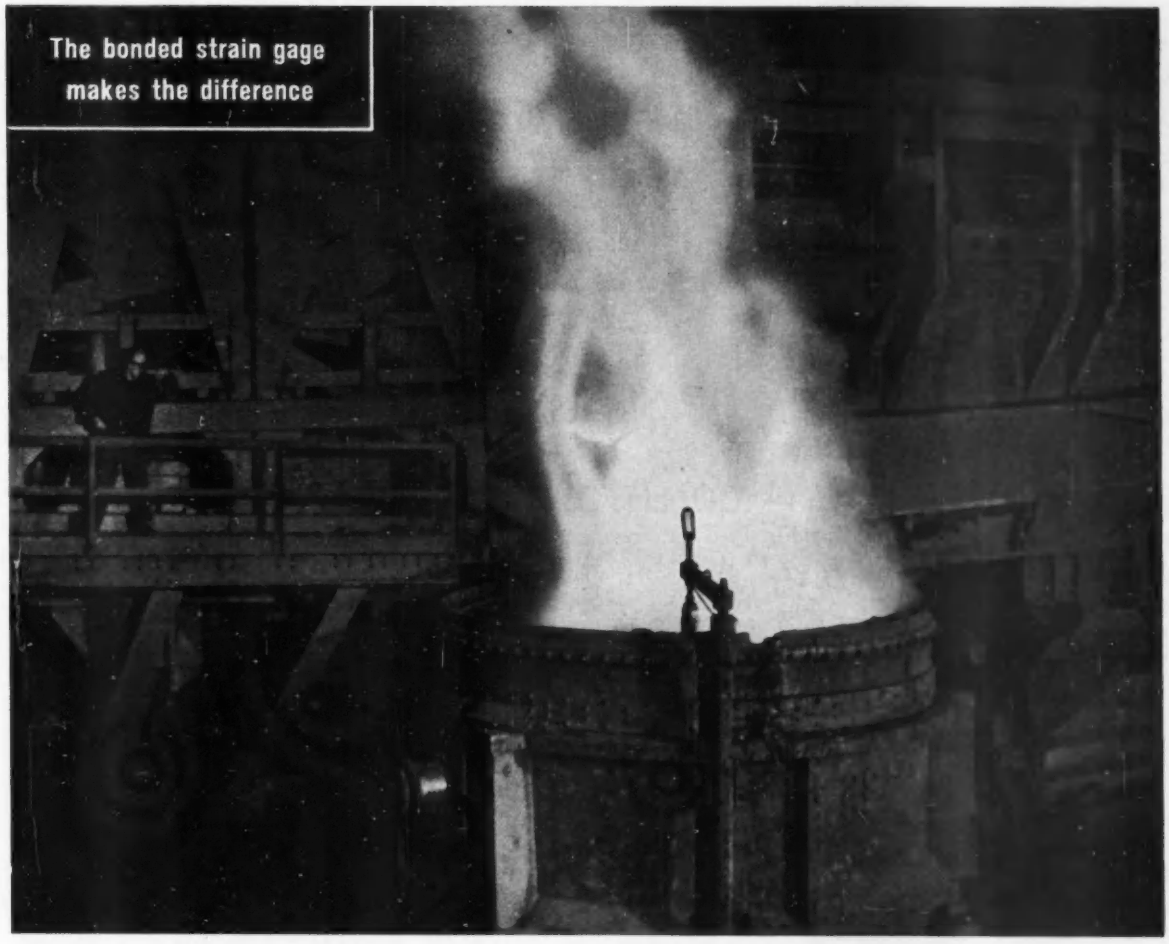
Most chemical and petroleum companies are still engaged in exploratory simulator studies, placing Britain a couple of years behind the U. S. in this work. A recent symposium (CtE, July '59, p. 40) showed steady work on the theory but little application.

▶ **Machine tool control—little commercial penetration**

Other than point-to-point positioning for jig borers and spotting tables, most projects are still restricted to manufacture of special parts for aircraft. Commercial applications are still firmly wedded to older copying techniques. What development engineers are searching for now are cheap systems. Their target is $6,000 per dimension with 0.002-in. accuracy.

▶ **Automated shipbuilding—a good start.**

Elimination of the moulding loft is planned based on the use of computers

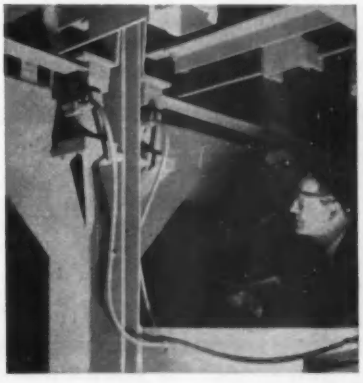


SR-4® system measures ladle additives automatically, helps turn out better ingots

A new means of adding ferro-alloys to steel automatically as it is poured from the ladle is quietly revolutionizing open-hearth steelmaking.

In developing its new Ladle-Additions Feeder, Blaw-Knox engineers turned to Baldwin-Lima-Hamilton for a rugged, accurate weighing system which would operate dependably under conditions where shock, overload and temperature change are the rule rather than the exception. The resulting system, now helping to save production time and improve steel quality in many installations, utilizes four 20,000-lb. SR-4® load cells on each additive bin. They send accurate weight signals to a B-L-H indicating and control system, which automatically feeds additive in precise amounts by weight.

In this, as well as countless other industrial applications, it is the SR-4® bonded strain gage which provides the required accuracy and dependability. Let B-L-H engineers solve your force measurement problems.



Two SR-4® load cells in adjacent bins of a Blaw-Knox Ladle-Additions Feeder. Special B-L-H system filters out vibration and shock signals, sending only precise weight data to instrument panel.

First in force measurement

BALDWIN · LIMA · HAMILTON

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SR-4® Strain Gages • Transducers • Systems

WHAT'S NEW

to calculate ship plate profiles coupled with automatic flame cutting systems.

▶Automatic inspection—lagging

The delay in this field is caused by Britain's lack of production runs long enough to approach the breakeven point for introduction of automatic techniques. The British market is looking for a machine that is adaptable for batch production runs of 1,000 or so. If successful, one new approach may cause Britain to leapfrog everybody: the use of optical techniques for dimensional inspection without jigging the product.

▶Automatic assembly—little movement

Low labor rates for semiskilled workers still fail to make automatic assembly attractive economically. What little activity there is in radio set production, for instance, follows American practices.

▶Automatic identification—set

Set to break in the U.K. now is the identification of shapes and code marks on mixed products flowing on conveyor lines. Also, a coded photoelectric recognition system on London buses gives centralized information on bus positions along their routes. Experimental studies are under way for railroad marshalling yards.

▶Automatic warehousing—ready

Britain lags behind the U. S., but current high user interest and the setting up of a new British combine with a license from Industrial Electronic Engineers, Inc. of N. Hollywood, Calif., (CtE, March '60, p. 206) is expected to move this category up the list of practical automation hardware within the next few years.

▶Road traffic control—a new entry

Necessity from the threatened strangulation of the country's road system by increased automobile production will call for highly automatic traffic signal control. A concentrated effort here would give the U.K. a lead in this field.

▶Monitoring production flow items—a good start

The steel industry has applied automatic monitoring to keep tabs on billets flowing through the mills. Since these systems are basically pioneered by the DSIR, this is likely to spread fast to other industries.

Dr. Foster blames Britain's overall patchy performance directly on a lack of information flow between manufacturer and user. Each has been waiting for the other to say what is wanted or what can be done. That's why he's sponsoring the national center as a means for getting the two together.

—Derek Barlow

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REGULATED POWER SUPPLY

Continuously Adjustable 0 to 300v, dc, at 200 ma *

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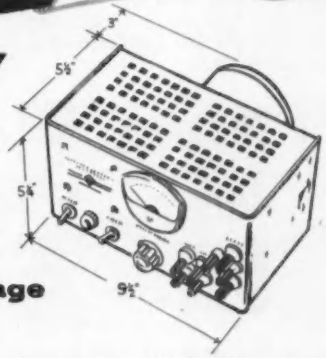
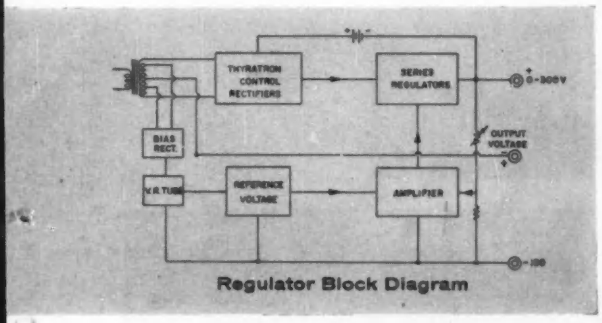
... two 6.3v, ac, unregulated outputs at 5a each
(may be connected in series or parallel)

... all from a compact package



120 Watts in 0.2 Cubic-Foot Package . . . Excellent performance is obtained by using two regulator circuits. A high-efficiency controlled rectifier maintains the optimum operating voltage for a series regulator, regardless of line-voltage changes, load changes, or changes in output voltage setting. Wide-band regulator circuits and high-frequency by-passing of the output make for low output impedance over a wide frequency range. A large capacity fan provides cooling without dependence on convection, permitting the stacking of any number of units.



Regulator Block Diagram

* **Ripple:** less than 1 mv (120c)
Regulation: 0.75v for ±10% line change; 0.1v from no load to full load
Output Impedance: Approximately 0.3Ω plus 10 μh

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AROUND THE BUSINESS LOOP

Putting Customer Satisfaction Where it Belongs— On Application Engineering

Adage has a unique way of insuring that its application engineers are satisfied with the design of the complex subsystems delivered to their customers: the application engineers design the units themselves and then perform final trouble shooting.

BOSTON—

A good application engineer knows exactly what his customer needs from a complex custom built subsystem like a digitizer—what special functions the equipment has to perform, what unique requirements have to be met. But the application engineer, and the customer, is not always happy with what an engineering department produces. Recognizing this conflict, Adage, Inc., a three-year-old manufacturer of digitizing equipment came up with a unique solution: the company has made its application engineers responsible for the design of the subsystems they have to sell.

Here's how it works. The company has designed standard functional circuit modules and reproduced the circuitry on transparent adhesive stickers that can be applied on a piece of tracing paper. The application engineer custom designs a digitizer by choosing the right stickers, applying them to a drawing, and then connecting them properly. The technique has cut delivery time in half.

To understand the why of this approach you have to take a look at Adage's business. Selling for an average of $7,000 a piece, the company's digitizing products are called on to perform a variety of functions such as analog to digital conversion, digital to

Circuit modules printed on stickers are selected and laid out by the application engineer.

Instructions for wiring cable harness are contained on magnetic tape.

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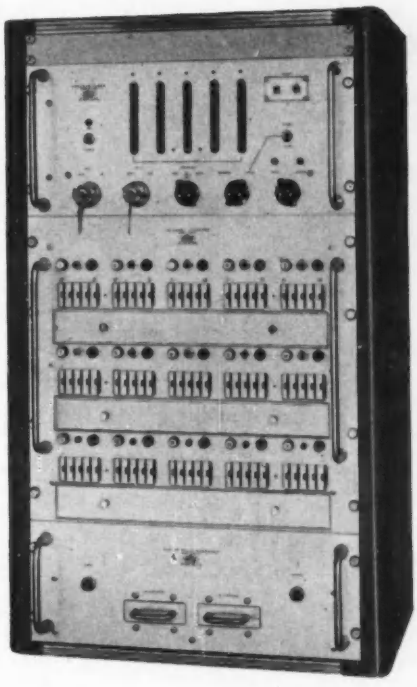
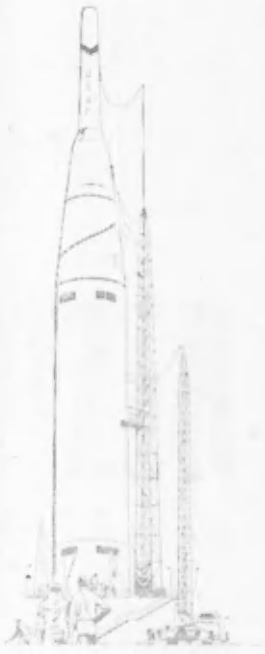
COUNTDOWN PROGRAM TIMING SYSTEM

typifies the versatile control and data systems Dymec builds for industry today





- **Precise timing through use of crystal time base and digital circuitry**
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IN USE TODAY

at a major missile test facility, the DY-5175 Countdown Program Timing System produces highly-accurate, predetermined control intervals for remote electrical actuation of motors, valves, cameras and control circuits. In the control of countdown functions, this System programs 15 multi-contact, heavy-duty relays in sequence, with time of operation of each control relay adjustable in millisecond increments.

The DY-5175 consists basically of a 5-decade preset counter with digital comparators, and 15 channel control circuits. At time-zero, the counter begins counting a crystal-controlled reference signal; when the count reaches the 5-digit number representing program elapsed time for each channel, the comparator initiates operation of that channel. Control functions can be started or stopped at any predetermined time setting. Signal lights indicate operation of the channel circuits and the output control relays. A built-in Safe/Armed test circuit permits making a "dry-run" prior to an actual countdown operation.

Safety features include a two-key start switch, a hold-to-operate switch, guarded time-interval switches and control relay safety plugs.

For counsel on systems appropriate to your needs, write direct or call your Dymec representative.

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WHAT'S NEW

analog conversion, high speed multiplexing of analog signals, limit testing –go/no-go checks, output drive amplification, and arithmetic operations. Of the first year's production, almost every unit was slightly different from any other, although all of them used certain common circuits. That's when Adage President F. Mansfield Young came up with the sticker idea.

The company chose 38 modules that seemed to be used frequently, reproduced the circuit diagrams on the stickers. Eventually the company will have 60 standard modules printed on stickers. To make the circuit tags, a draftsman first draws the circuit diagram five times final size. A commercial printer then reduces the drawing to a photo-offset plate and prints the circuits on plastic which has an adhesive backing. Cost of a single sticker is about 10 cents when printed in lots of 300.

• **Jig-saw pasteup**—To design a specific digitizer the application engineer studies customer specifications to decide which of the standard modules are required. If the application requires a module that is used rarely and no sticker has been printed, the engineer will have to draw that circuit by hand. After laying out the stickers on the drawing board and moving them around until he finds an optimum layout, he pastes them down. Then he adds any special items that have to be hand drawn. And finally he makes the proper wiring connections by drawing pencil lines between the proper pin connectors.

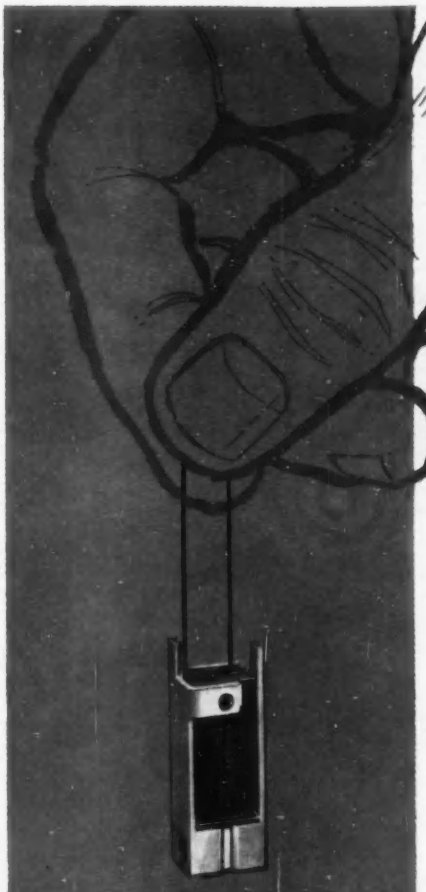
Because the actual digitizer is built from the pasteup drawing, no other drafting time is required. Adage found that it has cut drawing preparation time to two days from the 8 to 12 it formerly took a draftsman to prepare production drawings.

• **Production tricks**—Once the application engineers started designing with stickers, Adage executives took another look at the company's production techniques, looking for additional production time savers. As a result the company divided its production department into two major groups: one produced the printed circuit modules on a production line using conventional electronic manufacturing practices; the other builds wiring harnesses to match the application engineers' drawings.

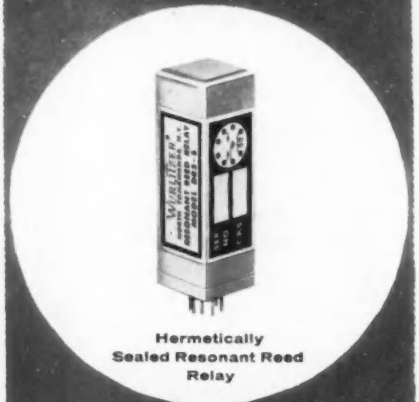
In this last operation Adage adopted a neat twist: the circuit wirer receives instructions from a magnetic tape instead of following a circuit diagram.

When the application engineer fin-

(*Continued on page 191*)



Uncased Resonant Reed Relay



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Frequency variation is less than 1/2% from – 60°F to +150°F.

Has application in:

- Frequency Sensing and Measurement
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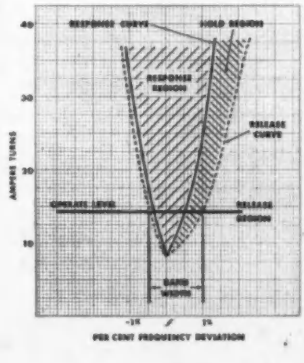
Size $1\frac{5}{32}$" x $\frac{7}{16}$" x $\frac{7}{16}$"—Weight 10/7 Grams

Available in uncased, hermetically sealed, and plug-in models for frequency range of 300 to 1000 cps. Other frequencies available.



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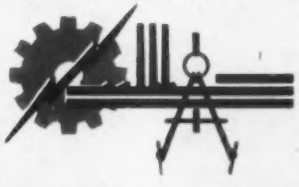

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Snap-Lock Limit Switches, developed by National Acme to meet rigid specifications, have become industry's standard for reliable "machine life" service. Latest and most advanced in the complete line is the SL2. Built with machine tool precision and ruggedness, it will give millions of fast, accurate contacts. Furthermore, it is water and oiltight and can stand the bruising conditions imposed by heavy-duty machine applications. You owe it to yourself to closely examine the *combination* of performance characteristics that assure completely reliable limit switch performance under the most extreme operating conditions.

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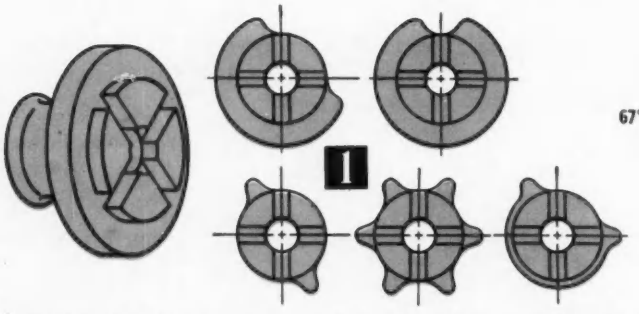

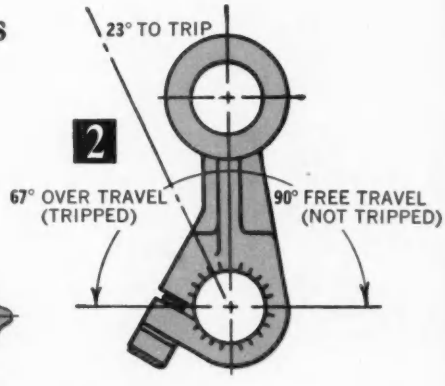

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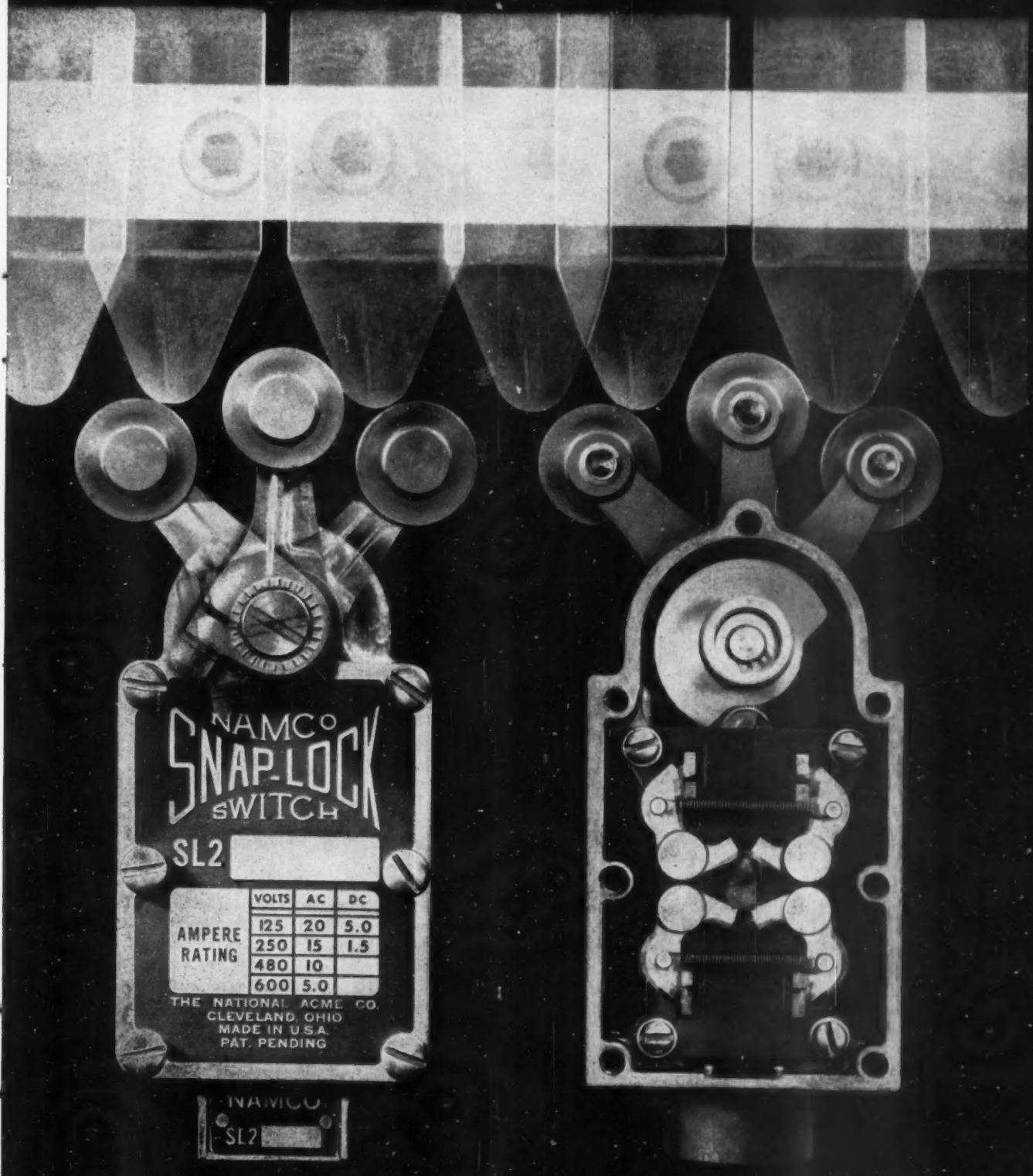
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Is Vaulting
Through Unexplored Space
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Orbital Path of Venus

At this moment Pioneer V, one of the most advanced space probe vehicles ever launched, is on a course toward the path of Venus—26 million miles from earth. Blasted aloft March 11 by a Thor Able-4 rocket booster, this miniature space laboratory will reach its destination in about 130 days.

The project, carried out by Space Technology Laboratories for the National Aeronautics and Space Administration under the direction of the Air Force Ballistic Missile Division, may confirm or disprove long-standing theories of the fundamental nature of the solar system and space itself.

Energy from the sun—captured by almost 5,000 cells mounted in the four paddles—is used to supply all of the electrical power to operate the sophisticated array of instrumentation packed into the 94-pound spacecraft which measures only 26″ in diameter.

By combining a phenomenal digital electronic brain (telebit) with a powerful radio transmitter inside the satellite, STL scientists and engineers expect to receive communications from Pioneer V at their command over interplanetary distances up to 50 million miles.

STL's technical staff brings to this space research the same talents which have provided over-all systems engineering and technical direction since 1954 to the Air Force missile programs including Atlas, Thor, Titan, Minuteman, and related space programs.

Important positions in connection with these activities are now available for scientists and engineers with outstanding capabilities. Inquiries and resumes are invited.

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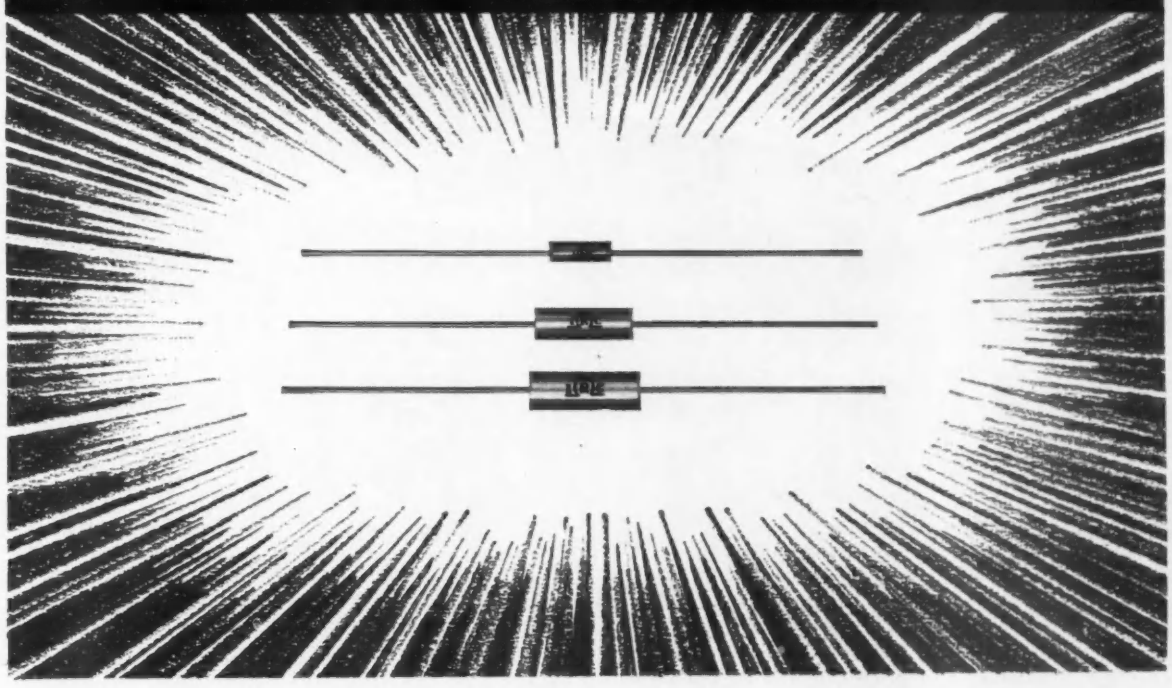


Precision Film advantages offered economically by IRC Stabaloy* Resistors with TC not exceeding 150 ppm

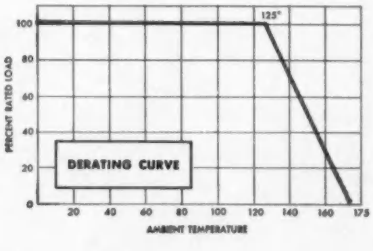
IRC Stabaloy resistors feature an element produced by an exclusive IRC process. It is free from the inherent problems associated with wire wound precision resistors, and provides a saving of over 50% in size and weight.

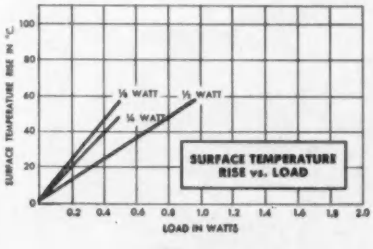
Capacitance and inductance are inherently low so that Stabaloy resistors are ideal for high frequency applications. Voltage coefficient is negligible.

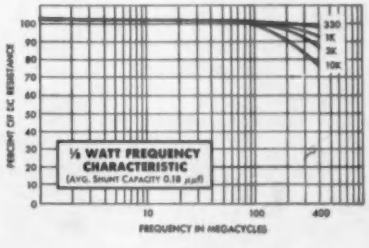
IRC Stabaloy resistors have a maximum temperature coefficient of ±150 ppm, and they provide the operating characteristics of precision resistors costing much more.

IRC Stabaloy resistors are available in 3 standard sizes—⅛ watt, ¼ watt and ½ watt. The illustrations above are actual size. Standard tolerance is ±1.0%. Tolerance of ±0.5% is available. For most of the advantages of precision film resistors at an economical price, examine carefully the characteristics of IRC Stabaloy resistors. Write for Bulletin AE-10. International Resistance Co., Dept. 244, 401 N. Broad St., Philadelphia 8, Pa.

*Registration pending.

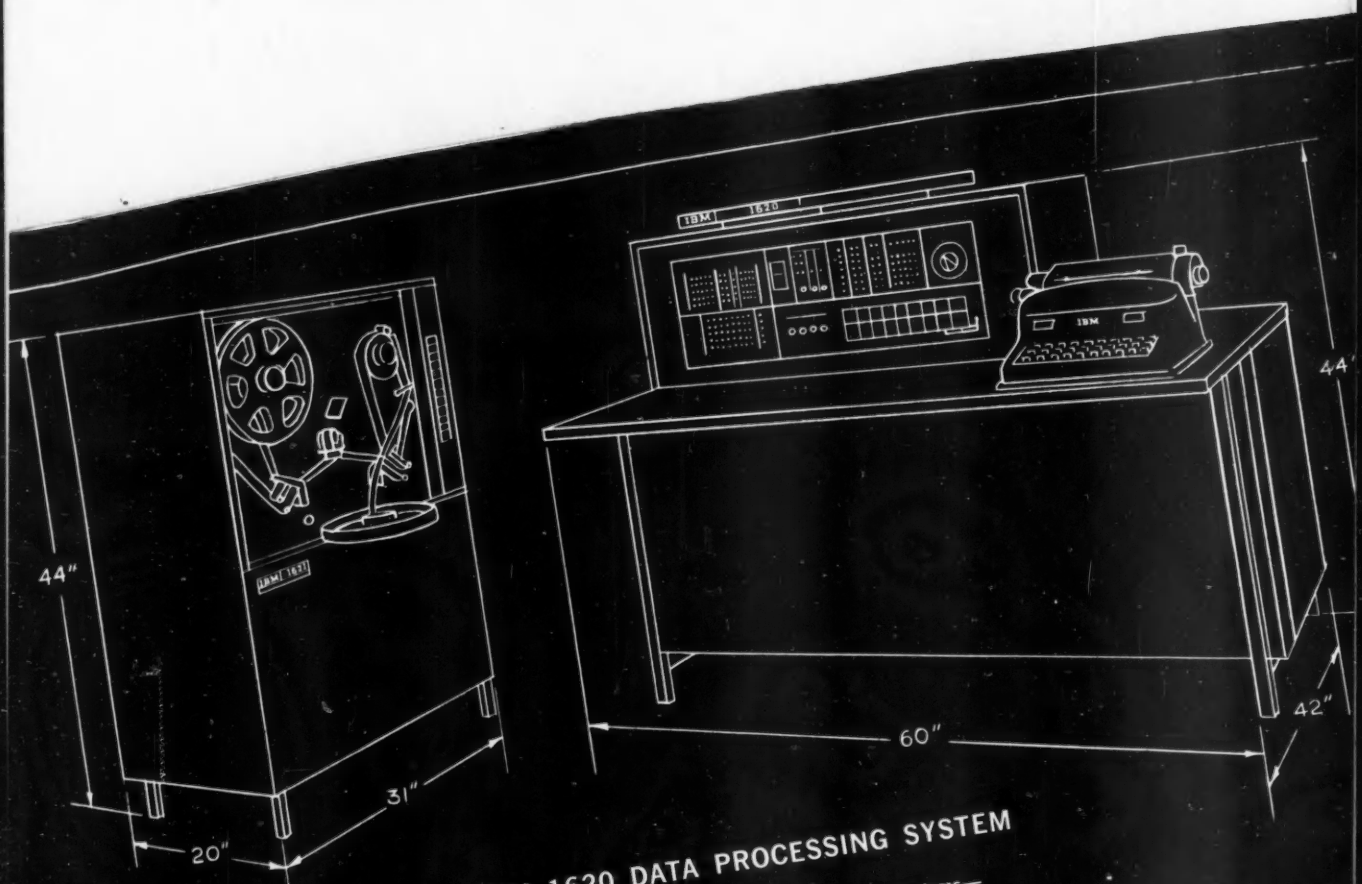






IRC

Leading supplier to manufacturers of electronic equipment



SPECIFICATIONS: IBM 1620 DATA PROCESSING SYSTEM

Core storage—20,000 digits
Automatic operation—stored programming
High computing speed—20 microsecond machine cycle
Powerful instructions with two data addresses
Decimal and alphabetic
Variable field and record length—any size numbers

Advanced programming systems—
Fortran and symbolic programming
Compatibility with other computers through Fortran
Simple console with logging features
Self checking throughout
Transistorized circuitry—
compact, economical, reliable
Paper tape input and output

The 1620 will meet technical computing requirements too complex for the conventional desk-type calculator. It provides many advantages of larger systems at a much lower cost. In addition, it can be used to support other data processing systems such as the IBM 650, 704, 705, 709, 7070 and 7090.

Information enters the system from the typewriter of the 1620 Central Processing Unit, or from the 1621 Paper Tape Reader. Output is to the typewriter or 961 Tape Punch.

Machine	Weight in lbs.	Current Requirements	Power cord	Interconnecting cable	Heat Load Specification BTU/Hr
1620	1,000	20 Amps., 115 Volts, single phase	10′ 3-Wire for 115 and 230 Volts	10′ signal	5,000
		10 Amps., 230 Volts, single phase		10′ power	
		6.5 Amps., 208 Volts, three phase	10′ 4-Wire for 208 Volts	—	2,000
1621	280	—	—	—	

FREE YOUR ENGINEERING STAFF FOR MORE CREATIVE WORK . . .

IBM 1620 LOW-COST, DESK-SIZE COMPUTER

RELIEVES YOUR STAFF OF TIME CONSUMING WORK

...SOLVES WIDE RANGE OF SPECIALIZED PROBLEMS

Problems that used to tie up your engineering staff for days can now be solved . . . with electronic accuracy . . . in minutes! The IBM 1620 is a low-cost, desk-size engineering computer that solves a tremendous range of routine and specialized engineering problems quickly and easily. The 1620 offers you an economical way to increase staff productivity, helps pave the way for profitable growth.

The 1620 is easy to learn, easy to operate, easy to communicate with. It adapts readily to specialized and general problems such as design development, blending problems involving matrix arithmetic, research calculations with differential equations. It facilitates the development of mathematical models for plant and shop operation, and evaluation studies employing statistical techniques such as regression analysis.

IBM also makes available a comprehensive library of mathematical routines and programs as well as reliable customer engineering. These services supporting the 1620 are an important part of IBM Balanced Data Processing. They make it easy for you to make full use of the 1620 in your operations without delay. Like all IBM data processing equipment, the 1620 may be purchased or leased.

BALANCED DATA PROCESSING

IBM®

Dept. 805
International Business Machines Corporation
112 East Post Road, White Plains, N. Y.

Please send me further information and complete specifications for the IBM 1620 Engineering Computer. I am particularly interested in:

_____
(engineering application)

NAME _____

POSITION _____

COMPANY _____

ADDRESS _____

CITY _____ ZONE _____ STATE _____

Just 0.1° F Change Gets Fast Action...

from a Fenwal THERMOSWITCH® Unit

Extreme sensitivity is an outstanding control characteristic of the Fenwal Thermoswitch Unit. Its outer shell is the heat-sensitive element . . . strut-and-shell assembly responds almost instantly to a change in temperature. Contacts are totally enclosed and protected. There's no thermal lag in the unit. *Control is positive and precise.*

Thermoswitch Units are easily adjusted, and cover the range from −100 to +1500°F. They're available as miniature, surface-mounted, or immersion types, with special variations to resist corrosion, extreme vibration, and shock. Current ratings up to 10A-115VAC. *Whichever unit you choose will be rugged and compact — simple, reliable, and inexpensive.*

Build better temperature control into your products with Fenwal Thermoswitch Units. For illustrated booklet, write Fenwal Incorporated, 295 Pleasant Street, Ashland, Massachusetts.

Series 17000
THERMOSWITCH Unit

Another example of how **Fenwal** CONTROLS TEMPERATURE . . . PRECISELY

←CIRCLE 55 ON READER SERVICE CARD

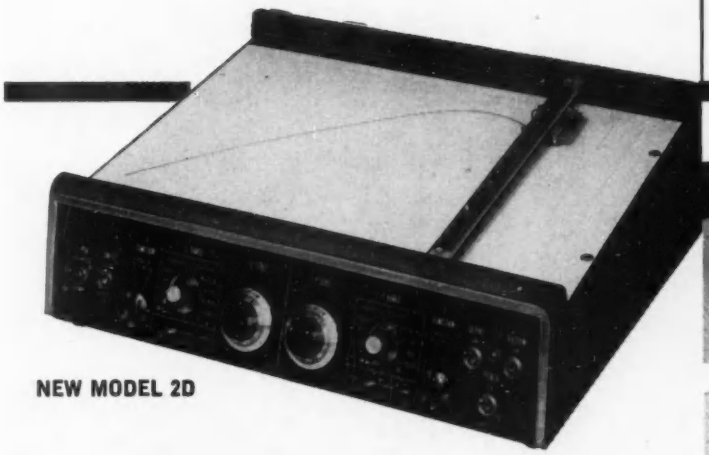
CIRCLE 56 ON READER SERVICE CARD

AUTOGRAF • AUTOGRAF • AUTOGRAF

Every feature you've ever wanted, now yours with this NEW MOSELEY X-Y RECORDER

- **New, integral AC/DC input**
- **No extra AC converter to buy**
- **Built-in X-axis time base**
- **Operates direct from transducer**
- **Accuracy, resolution ± 0.25%**
- **Local or remote operation**

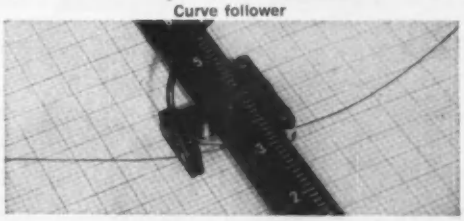
and look at the broader utility you get with these precision Moseley accessories



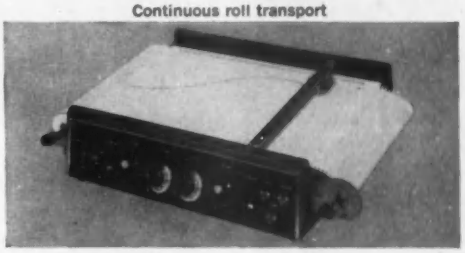
NEW MODEL 2D

Digital character printer

Curve follower



Continuous roll transport



"Pull-through, tear off" transport

Model 2D is a significantly advanced X-Y Recorder offering virtually every useful Recorder capability, plus a new control panel arrangement insuring maximum operating convenience. Brief specifications are: Input range 7.5 mv to 150 v on X-axis; 5 mv to 100 v on Y-axis. X-axis time base, 5 steps, 7.5 to 750 secs. Input resistance 200,000 ohms/v, accuracy and resolution ± .2%, zero offset, pen speed 20 in/sec each axis, vacuum paper hold-down.

Call your Moseley AUTOGRAF Recorder representative today or write direct for detailed data on Model 2D and accessories.

Data subject to change without notice.

Pioneer and leader in X-Y and Strip-Chart Recorders

AUTOGRAF recorders

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Dept. H-5, 409 N. Fair Oaks Ave., Pasadena, California
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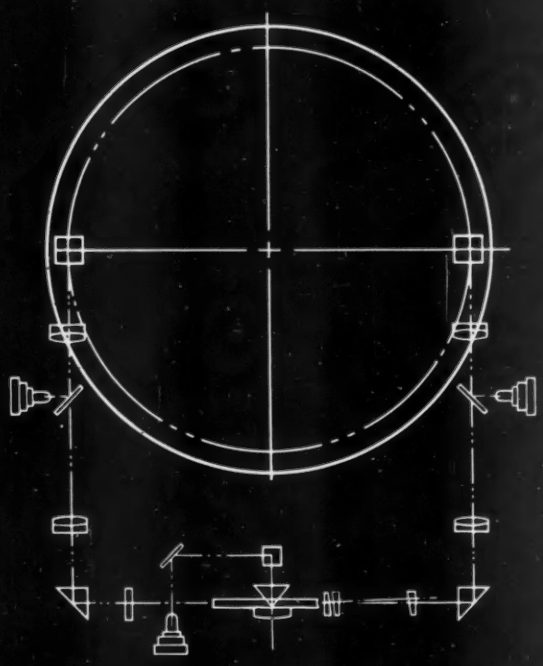
Now there are 2 ways to read angles...

Photoelectrically with a Gurley Encoder

Optically with a Gurley UNISEC®

Angles may now be read photoelectrically with the Gurley Precision Shaft Position Encoder. The information can be transmitted anywhere, in digital form.
Write for Bulletin 8600.



You can read shaft positions to one second of arc —directly—with the Gurley UNISEC,® an Optical Coincidence Reading System, complete with a precision glass circle.
Write for Bulletin 7500.

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SOLA AC and DC voltage regulation

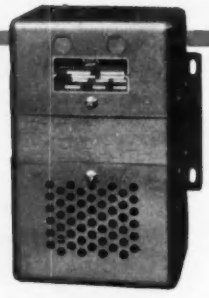
Continuous, automatic, maintenance-free

Sola Constant Voltage Transformers and Regulated DC Power Supplies provide dependable, regulated output voltage. Their output regulation is unaffected by wide variations in input voltage.

Sola CV Transformers are static-magnetic regulators with completely automatic, continuous regulating action. Their response to variations in input voltage is usually 1.5 cycles or less. They have no moving or renewable parts and require no maintenance.

Each Sola Regulated DC Power Supply incorporates a constant voltage transformer in combination with a semi-conductor rectifier and a high-capacitance filter section. This combination makes the power supply compact, dependable, and efficient; and assures sustained output voltage in the face of pulse or intermittent loads, or heavy, short-time overloads.

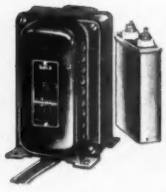
Sola Constant Voltage Transformers



Standard Sinusoidal Type *provides voltage regulation of ±1% with primary voltage variations as great as ±15%. With less than 3% total rms harmonic content in their output voltage wave, these units are desirable for use with equipment having elements sensitive to power frequencies harmonically related to the fundamental. Available in nine ratings, 60va to 7.5kva.*

Normal-Harmonic Type *also provides ±1% regulation at somewhat less cost. This group has an average of 14% total rms harmonic content in its output voltages and is suited to equipment not extremely sensitive to voltage wave shape. The series includes those mechanical designs specially engineered for use as built-in components. Nineteen stock ratings range from 15va to 10kva.*

Adjustable Sinusoidal Type *provides ±1% regulated voltage output—one output adjustable from 0-130 volts and one fixed at 115 volts. Has less than 3% total rms harmonic content in output voltage. Portable for use in shop or laboratory, or mount on standard relay rack.*



Electronic Power Type *regulators provide ±1% regulated filament voltage at 6.0 and 6.3-volt levels; or a combination of plate and filament voltages regulated ±3% for ±15% input variations. Filament regulators are available in ratings from 2.3 to 25 amps. One model is specially designed for portable lab or shop bench use; it has a 30va rating. Combination plate/filament regulators, in three stock sizes, are designed to operate with commonly-used rectifier tubes.*

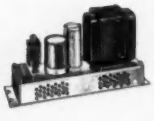
Custom-designed units *can be supplied in production quantities in ratings from 1va to 25kva to suit individual specifications. Custom designs can include special mechanical structures, various voltage ratios, special frequencies, compensation for frequency variations, multiple output voltages, three-phase service. Units can be manufactured to military specifications.*

For additional information on Sola Constant Voltage Transformers, write for Circular 26E-CV

Sola Constant Voltage DC Power Supplies

For intermittent...variable ...pulse...or high-current loads

Compact, rugged Sola Constant Voltage DC Power Supplies provide output regulated within±1% over line voltage variations as great as ±10%. Their output contains ripple voltage of 1% total rms or less. They have exceedingly low output impedance. Output is in the "ampere" range. The high, short-time overload capacity handles intermittent and pulse loads without serious voltage drop or damage to components.



Fixed-output-voltage designs *are available in six stock models with ratings from 24v @ 6a to 250v @ 1a. They are extremely compact, light-weight, and moderately priced in proportion to their power output and performance.*

Adjustable-output designs *provide a considerable range of regulated dc test voltages. Accessory handles offer portability and permit self-stacking. Six models are available with outputs ranging from 5v @ 7a to 400v @ 0.6a.*

For additional information on Sola DC Power Supplies, write for Circular 26E-DC

SOLA

SOLA ELECTRIC CO.

BPC

Sola Manufactures: Constant Voltage Transformers, Regulated DC Power Supplies, Constant Wattage Mercury Lamp Transformers and Fluorescent Lamp Ballasts

A Division of Basic Products Corporation

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300 HOUSINGS PER HOUR

produced on Greenlee machine— with assist from VICKERS *hydraulics*

Here's a Greenlee transfer machine that produces 300 steering gear housings per hour while performing a total of 114 close tolerance machining operations. This outstanding performance record is achieved because the machine combines advanced design ideas with the best available components.

Self-contained Vickers hydraulic power packages provide controlled power for clamping the pallet-mounted workpieces in precise position at each work station, driving transfer mechanisms and for movement of certain machine heads. These power packages are designed to JIC (Joint Industry Conference) standards which means easy maintenance and minimum downtime to you.

Vickers offers you power packages, either standard or custom engineered that provide an almost unlimited number of choices to meet your specific technical requirements. You can choose from the broadest product line in the industry any combination of controls for use with single, double, two-pressure or two-stage pumps (the latter for pressures to 2000 psi), and for variable and constant delivery pumps to 5000 psi. Your choice of components will be packaged with the size or shape reservoir best suited for your job.

Whether the Vickers power package you choose is standard or custom engineered, you save money and time because it comes *ready-to-go*—designed and assembled to the highest standard of quality by hydraulic specialists.

Get more data by writing today for Bulletin 5001C or by consulting your nearby Vickers application engineer.

VICKERS INCORPORATED 8514
DIVISION OF SPERRY RAND CORPORATION

Machinery Hydraulics Division
ADMINISTRATIVE and ENGINEERING CENTER
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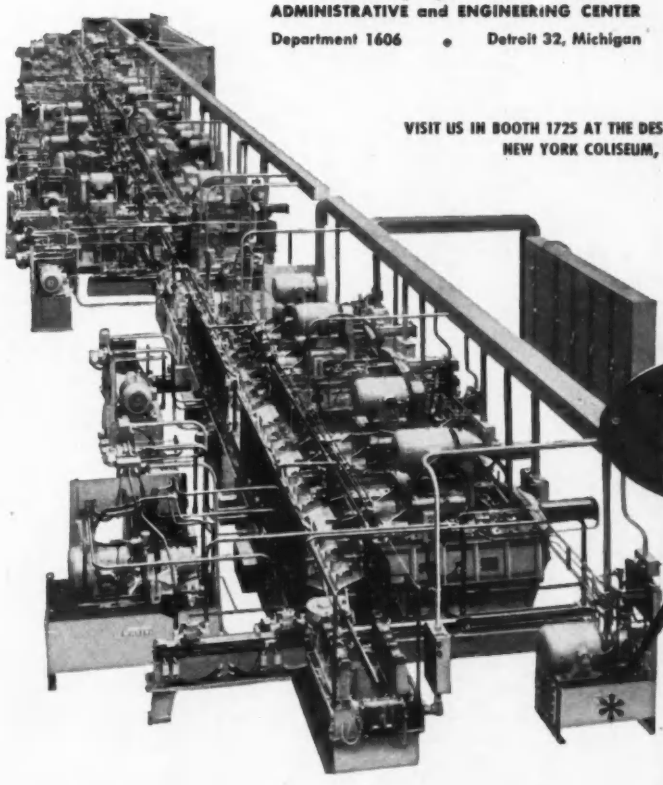
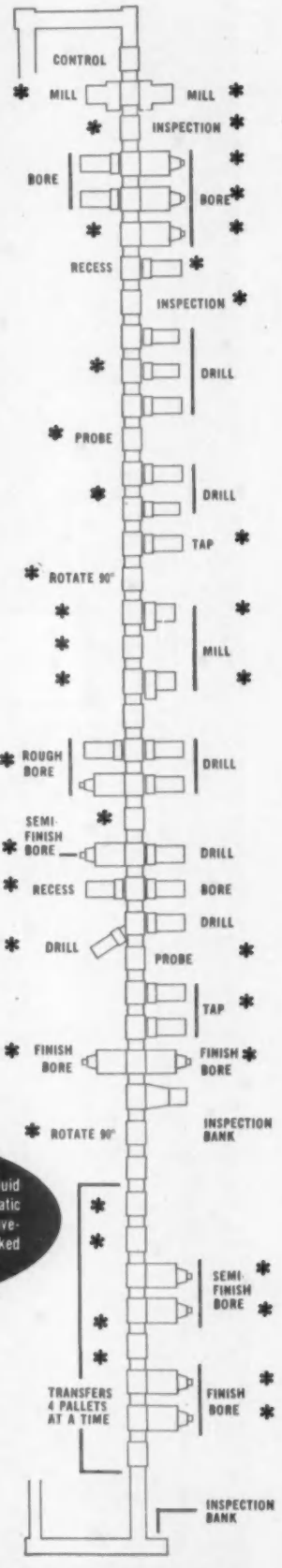
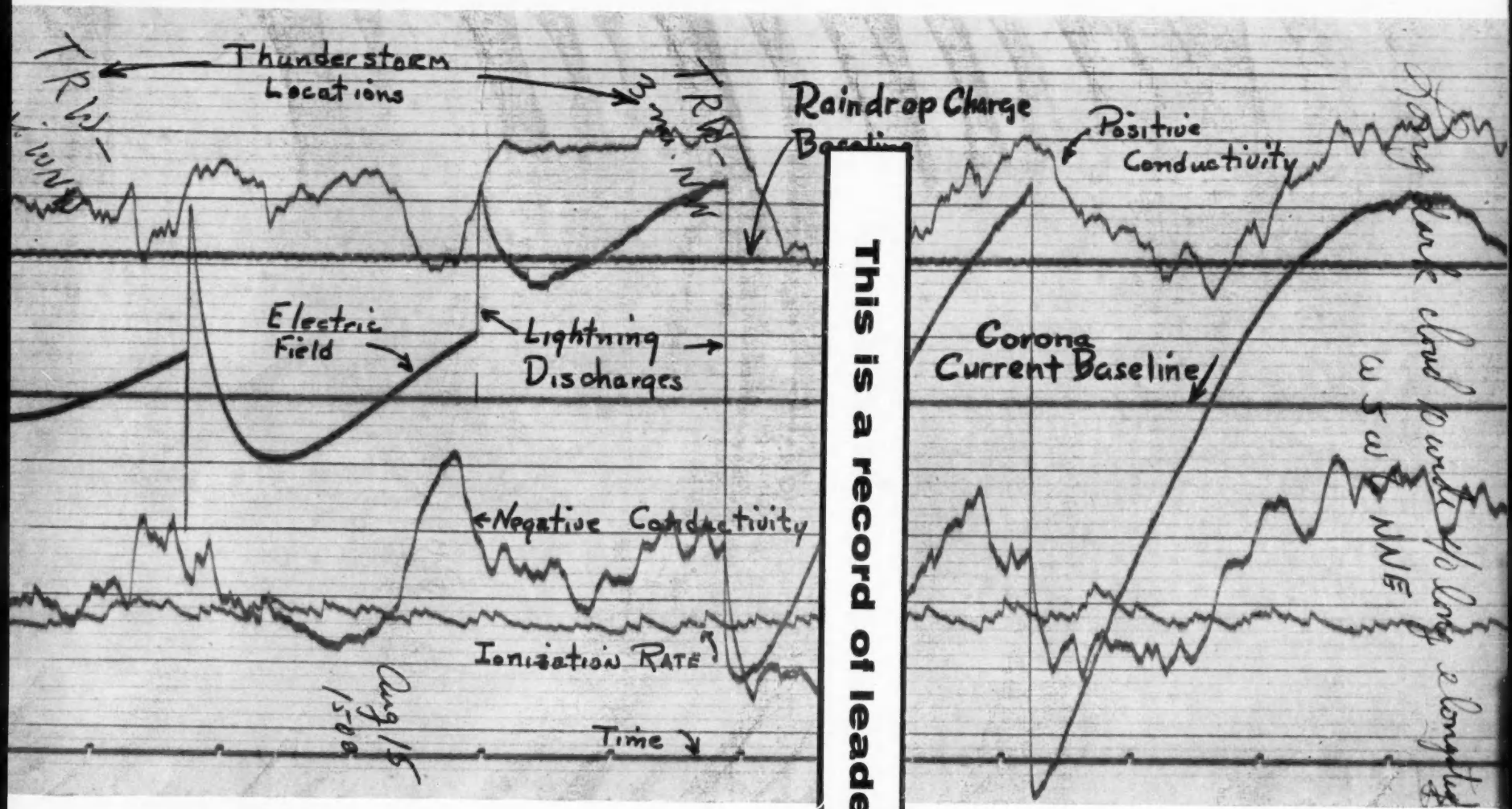


Vickers power packages supply fluid energy for fast, precise, automatic clamping, transfer and head movement at station locations marked with asterisk.





Honeywell 906A Visicorder record, actual size. Note longitudinal grid lines

This is a record of leadership

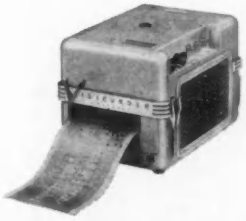
The U.S. Weather Bureau used a Honeywell Model 906B Visicorder Oscillograph to record directly this diary of a thunderstorm as it passed near the observation station on Mt. Washburn in Yellowstone National Park.

As the storm passed, the Visicorder measured and recorded 1) positive and negative electrical conductivity of the air, 2) the rate of ionization of air due to airborne radio-active particles and extra-terrestrial radiation, 3) the size and charge of individual raindrops, 4) the corona discharge current from an insulated tree and from a 4′x 6′ grass plot to determine current flow from the earth's surface to charge centers in the clouds, 5) times of camera exposure photographing cloud droplet size and electrical charge, 6) atmosphere potential gradient, and 7) time.

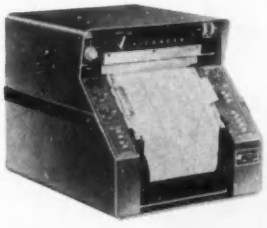
The Visicorder made this and many other records on Mt. Washburn without the use of power amplifiers. This feature, plus the extreme portability of the Visicorder, made it the ideal oscillograph for use in these studies.

Byron Phillips, U. S. Weather Bureau Scientist, monitors thunderstorm data as it is recorded by the Honeywell Model 906 Visicorder.

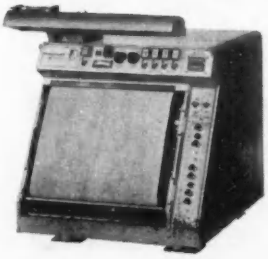
in weather research



Recent Models of the **906 Visicorder** incorporate time lines and grid lines and record up to 14 simultaneous channels of data.



The NEW Model **1108 Visicorder** with many automatic features and the convenience of push-button controls, is ideal for intermediate uses requiring up to 24 channels of data.



The Model **1012 Visicorder** is the most versatile and convenient oscillograph ever devised for recording as many as 36 channels of data.

The Honeywell Visicorder is the pioneer, completely proven, and unquestioned leader in the field of high-frequency, high-sensitivity, direct-recording ultra-violet oscillography. Here are some of the reasons why Visicorders provide the most accurate analog recordings available: constant flat response and sensitivity of galvanometers; grid-lines simultaneously recorded with traces to guarantee exact reference regardless of possible paper shift or shrinkage; flash-tube timing system for greater accuracy of time lines; superior optics for maximum linearity of traces.

No matter what field you are in . . . research, development, computing, rocketry, product design, control, nucleonics . . . the high-frequency (DC to 5000 cps) Visicorder Oscillograph will save you time and money in data acquisition.

Call your nearest Minneapolis-Honeywell Industrial Sales Office for a demonstration.

Reference Data: write for Bulletins 1108, 1012 and HC-906B

Minneapolis-Honeywell Regulator Co.
Industrial Products Group, Heiland Division
5200 E. Evans Avenue, Denver 22, Colorado

Honeywell

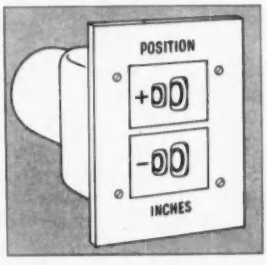
Industrial Products Group

FROM HONEYWELL... A DIAMOND JUBILEE PARADE OF PRODUCTS

Veeder-Root READOUT Bulletin

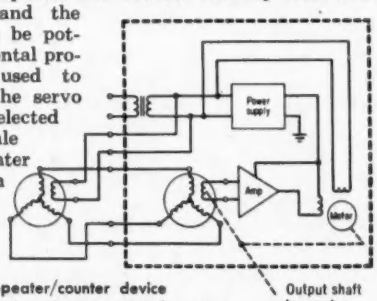
Readout Counter used in Tape Preparation for Machine Tool Control

A Veeder-Root Series 1538 Remote Data Readout Counter provides tape feed control for the motorized tape punching unit of the new Potter & Johnston Tape Control System. The tape punch is used to program machine functions on P & J Automatic Turret Lathes. The counter automatically controls the amount of tape feed required for each turret face involved, and stops the tape at preselected address points. When the correct address point is reached, a combination of holes representing the machine command is punched into the tape. Counter is automatically reset for each turret face.



Servo Repeaters Drive Counters to Indicate Lineal Motion*

One of the ways to take advantage of digital readout for indicating and recording information at remote points is through servo repeaters. Applications in aircraft, for altimeters, navigational displays and similar instrumentation, suggest many other opportunities to use counters for more positive indication and control. A typical "system" is shown here where a counter is used for indicating nuclear reactor rod position. The servo repeater and counter actually form one packaged unit, and the whole device can be potted for environmental protection. When used to drive counters, the servo gear ratio is best selected to provide full scale travel of the counter for one revolution of the control transformer shaft.



Typical servo repeater/counter device that converts synchro data to digital readout.

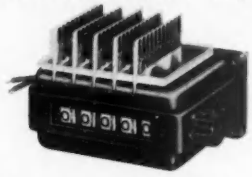
Let Veeder-Root help you make Counters do more! Extensive design experience and precision production techniques make it possible for Veeder-Root to help you solve a wide variety of digital, readout, control and recording problems with counters — from the simplest ratchet to advanced readout and navigational devices. Send for information on specific applications or contact your local Veeder-Root Counting Engineer.

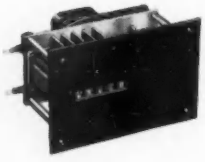
*Reprinted from CONTROL ENGINEERING June 1959. Copyright© 1959 by McGraw-Hill Pub. Co., Inc. All rights reserved.

Veeder-Root Readout Device

This is the basic series of Remote Data Readout Counters. Some are available for standard applications, or design variations will be submitted based on requirements. They function basically as analog to digital converters.

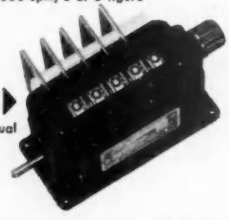
Series 1538/electrical reset/ electrically actuated. Speed 1000 cpm, 3 or 5 figure





Series 1538/electrically actuated/ manual reset. Speed 1000 cpm, 3 or 5 figure

Series 1606/mechanically actuated manual reset standard; bi-directional (non-reset) available. Speed 5000 cpm, up to 5 figures



Veeder-Root

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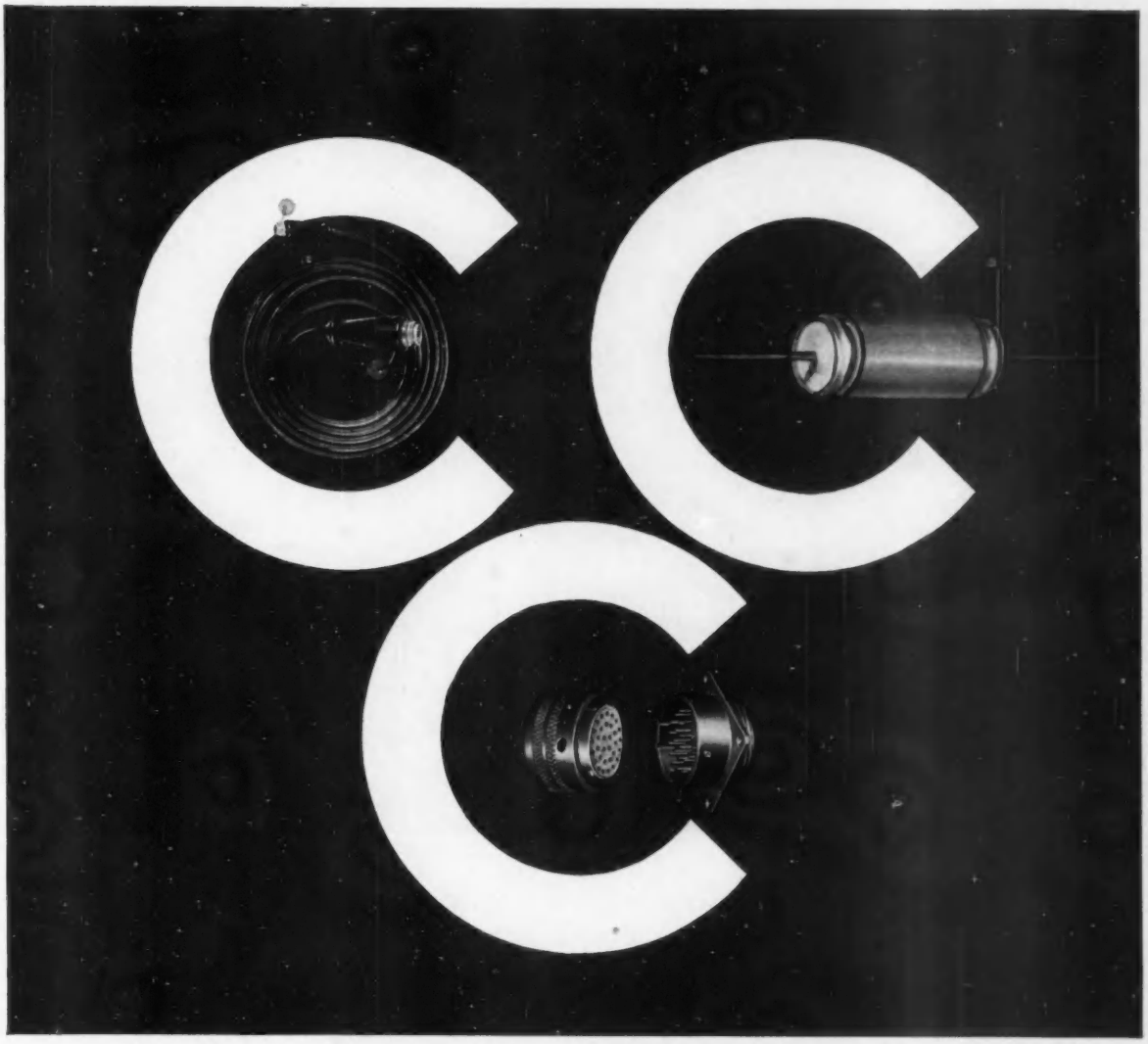

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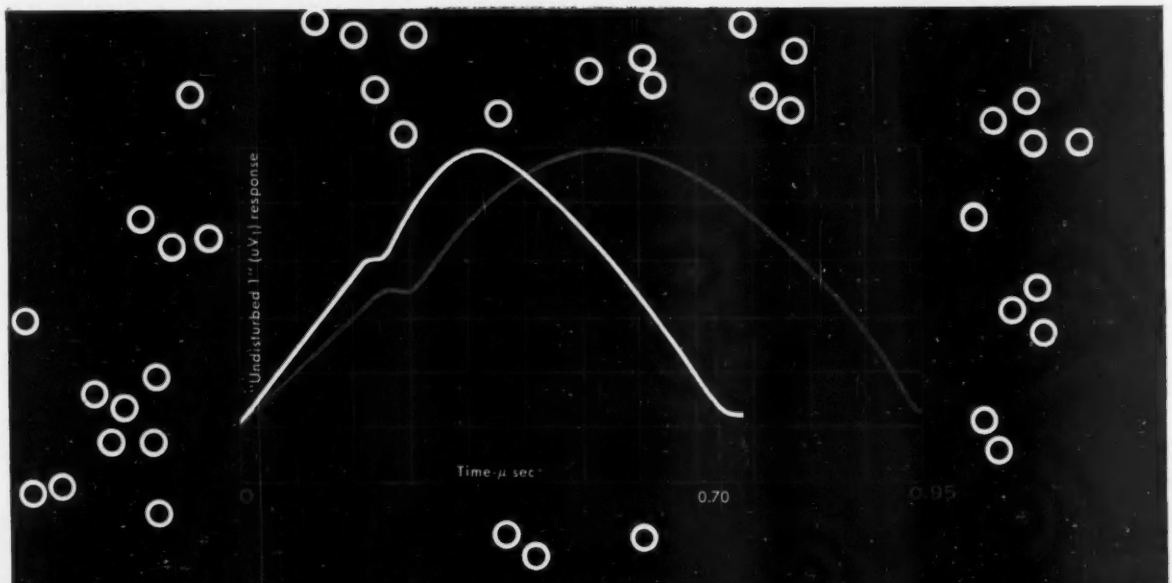


Another major addition to the RCA Ferrite Line

NEW RCA MEMORY CORE

Switches in 0.7 μsec

RCA Ferrite line now offers a choice of memory cores with faster switching times or reduced power requirements

RCA's new memory core 227M1 (XF-4138) with 0.7 μsec switching time, now opens up a wide choice of design possibilities for military and commercial computers. With the announcement of this new core, RCA now offers:

- 227M1 (XF-4138) for fast switching
- 226M1 (XF-4028) for *reduced* power requirements with *increased* operating margins
- 224M1 (XF-3018H) for standard coincident-current memory applications

See chart for comparative operating characteristics. These cores are part of RCA's comprehensive line of ferrite cores, transfluxors, and other magnetic memory and switching devices.

Systems Engineering Service

Your local RCA Field Representative is prepared to furnish a completely coordinated service, including transistor, ferrite, and memory-systems application assistance. Call him today. For technical literature on RCA Ferrite cores and memory devices, write RCA Commercial Engineering, Section E-56-NN, Somerville, N. J.

NOMINAL OPERATING CHARACTERISTICS AT 25°C

Type	New Feature	Size	Full Driving Current (Im) (ma)	Partial-Write Current (Ipw) (ma)	Pulse Rise Time (t_r) (μ sec)	Switching Time (t_s) (μ sec)	Response "Undisturbed 1" (uV_1) (mv)	Response "Disturbed 0" (dV_1) (mv)
226MI (XF-4028)	Lower Drive	.050"x.030"x.015"	400	200	0.2	0.95	85	10
224MI (XF-3018H)	Present Standard	.050"x.030"x.015"	500	250	0.2	0.95	75	8.5
227MI (XF-4138)	Faster Switching	.050"x.030"x.015"	500	250	0.2	0.70	105	13

ANOTHER WAY RCA SERVES YOU THROUGH ELECTRONICS

RADIO CORPORATION OF AMERICA

SEMICONDUCTOR AND MATERIALS DIVISION — SOMERVILLE, N. J.

RCA SEMICONDUCTOR & MATERIALS DIVISION FIELD OFFICES

EAST: 744 Broad Street, Newark, N. J. HUmboldt 5-3900

NORTHEAST: 64 "A" Street Needham Heights 94, Mass. HIllcrest 4-7200

EAST CENTRAL: 714 New Center Bldg. Detroit 2, Mich. TRinity 5-5600

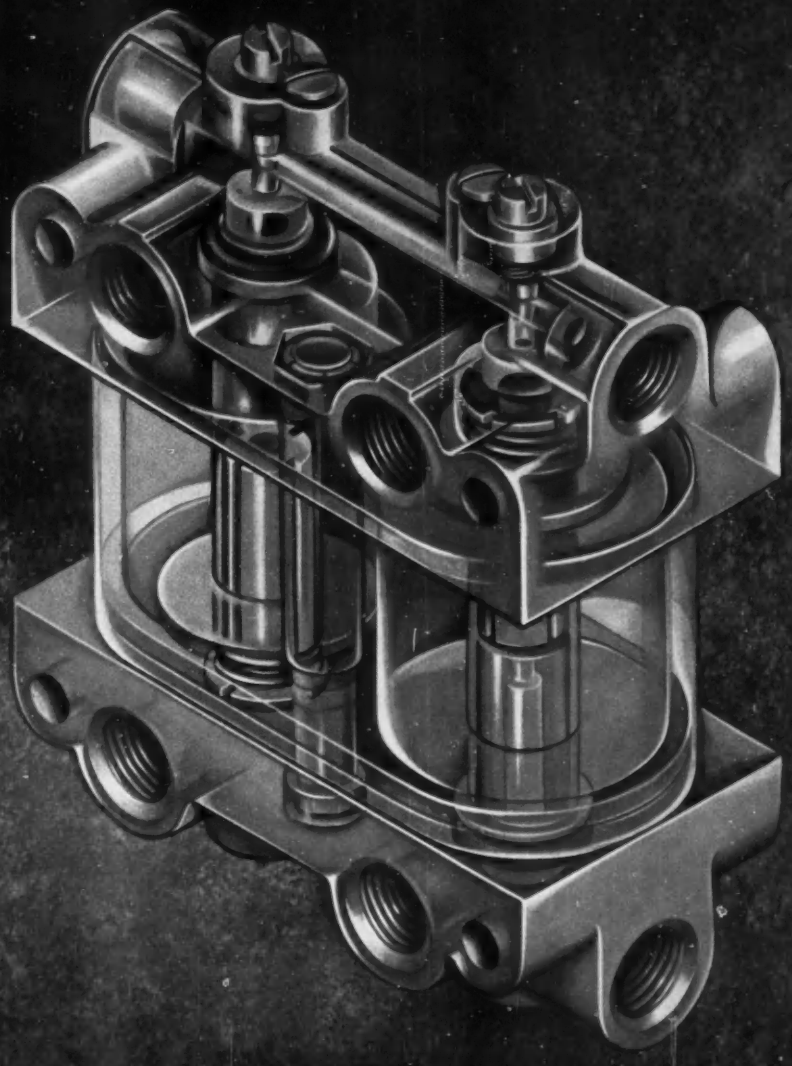
CENTRAL: Suite 1154 Merchandise Mart Plaza Chicago, Ill. WHitehall 4-2900

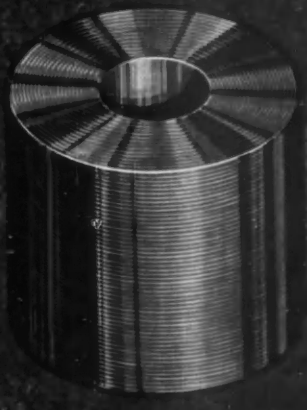
WEST: 6355 E. Washington Blvd. Los Angeles, Calif. RAymond 3-8361

SOUTHWEST: 7905 Empire Freeway Dallas 7, Texas. FLeetwood 7-8167

GOV'T: 224 N. Wilkinson St. Dayton, Ohio. BAldwin 6-2366

1625 "K" Street, N.W., Washington, D.C. District 7-1260





Compact 4-way

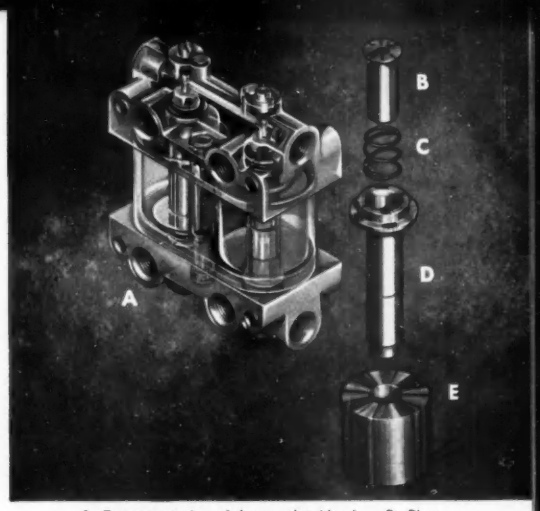
SKINNER

Solenoid Valves

assure precise cylinder control

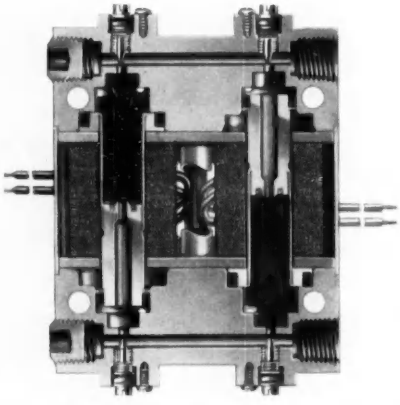
Here's how accurate, dependable operation is built into SKINNER 4-way solenoid valves

- **Precise flow control**—by adjustable metering
- **Compact, direct acting**—two 3-way valves in one housing
- **Durable and corrosion resistant**—stainless steel internal parts
- **Leakproof, bubbletight sealing**—soft, synthetic inserts
- **Positive operation mounted in any position**—spring-loaded plungers
- **Underwriters approved**—wide selection of coils, voltages and frequencies
- **Wired from front or rear**—housing easily reversed
- **Adaptable to many uses**—optional porting arrangements



A. Transparent view of 4-way solenoid valve B. Plunger
C. Plunger return spring D. Sleeve E. Coil

SKINNER four-way solenoid valves available in three basic types



The Skinner V9 solenoid valve is two 3-way valves in one compact housing. Both valves may be independently controlled and metered to provide accurate, dependable control of single- or double-acting cylinders, or larger pilot-operated valves.

V9 types are available without adjustable flow and with metering at both exhaust ports, both inlet ports or full metering of all ports.

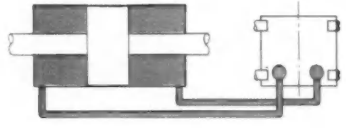
▪ ▪ ▪

For complete information, contact a Skinner Distributor listed in the Yellow Pages or write us at the address below.

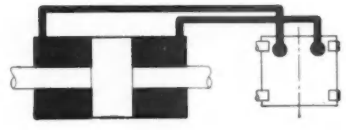
V9 SERIES SPECIFICATIONS

Media—air, hydraulic oils, inert gases
Orifice Diameter—$\frac{3}{64}$", $\frac{1}{16}$", $\frac{3}{32}$", $\frac{1}{8}$"
Pipe Size—$\frac{1}{4}$" NPTF
Maximum Operating Pressure Differential—0 to 150 PSI (up to 225 PSI also available)
Temperature Range—minus 40°F. to plus 180°F.
C_V Factor—$\frac{3}{64}$" .052, $\frac{1}{16}$" .095, $\frac{3}{32}$" .156, $\frac{1}{8}$" .214
Mounting—$\frac{1}{4}$" through-bolt holes.

Normally closed—normally closed V933 valves with a neutral position. Generally applied on double-acting cylinders where the piston is in a neutral position without pressure when both coils are de-energized. This permits manual shifting of the piston without operating the valve.



Normally open—normally open V955 valves with a neutral position. Generally applied on double-acting cylinders where both sides of the piston are to be open to pressure when both coils are de-energized. Under certain conditions, the first operating stroke of double-acting cylinders will be smoother with this valve in use.



Normally closed—normally open V935 valves with no neutral position. Generally applied on double-acting cylinders where the piston is to be in retracted or extended position with pressure when both coils are de-energized. Wiring is simple—both coils are operated simultaneously and can be controlled by one single-pole, single-throw switch.

When you specify solenoid valves, specify Skinner. Skinner solenoid valves are distributed nationally.

SKINNER ELECTRIC VALVES®
THE CREST OF QUALITY

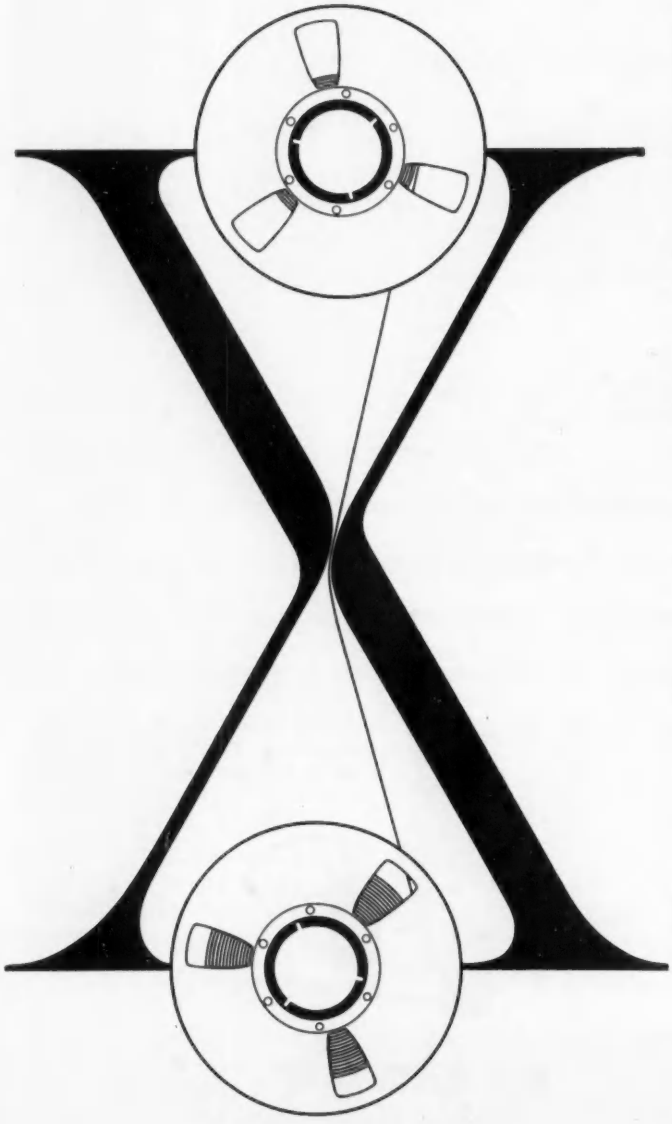
SKINNER ELECTRIC VALVES

SKINNER ELECTRIC VALVE DIVISION,
THE SKINNER CHUCK COMPANY • NEW BRITAIN, CONNECTICUT, U.S.A.

PRINTED IN U.S.A.

NO DOUBT ABOUT IT—

"SCOTCH" BRAND Sandwich Tapes wear 10 times as long without errors



IN THAT NARROW LITTLE LIFELINE OF DATA known as magnetic tape, a miss is magnified into a mile. A missed bit, or one picked up by error is confusing, frustrating and time-consuming. If you're in doubt about the kind of performance you're getting, perhaps "SCOTCH" BRAND Sandwich Tapes can solve some of your tape and equipment problems.

The exclusive construction of the Sandwich Tapes combats the causes of error because it eliminates the source—oxide rub-off and head build-up. Tests prove it wears a minimum of 10 times as long as ordinary tapes before it errs. As a by-product, you can rely on it to drastically reduce maintenance and replacement costs on equipment.

The Sandwich is constructed as shown in the diagram at the right. The famous "SCOTCH" BRAND high potency oxide coating is sandwiched between a tough polyester base and a 50 micro-inch layer of plastic. Since the oxide is never in contact with the head, tape movement is smooth and low in friction—easy on both tape and equipment. Oxide can't rub off and distort valuable data.

Yet, the real meat of this remarkable Sandwich is the "SCOTCH" BRAND high potency oxide coating. Even under the protective plastic, the oxide's potency is quite sufficient to pick up 500 pulses per inch—and give desirable high-frequency response in many AM, FM and PDM applications. Sandwich Tape is but one of the developments to come out of 3M research—the same research responsible for "SCOTCH" BRAND Video Tape—the first video tape in commercial use.

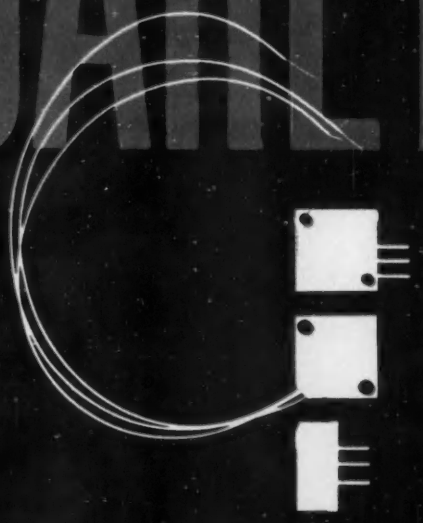
Whatever your application—you'll find the right tape for reliable, error-free performance in the "SCOTCH" BRAND line-up. Check them all. *High Resolution Tapes 158 and 159* pack more bits per inch, offer either standard or extra-play time. *New Heavy Duty Tapes 198 and 199* offer good resolution and exceptional life even in poor environments. *High Output Tape 128* gives top output in low frequencies, even in temperature extremes. And *Standard Tapes 108 and 109* remain the standard of instrumentation.

Your 3M Representative is close at hand in all major cities—a convenient source of supply and information. For details, consult him or write Magnetic Products Division, 3M Co., St. Paul 6, Minnesota.

SCOTCH BRAND MAGNETIC TAPE
FOR INSTRUMENTATION

MINNESOTA MINING AND MANUFACTURING COMPANY
...WHERE RESEARCH IS THE KEY TO TOMORROW

SQUARETRIM



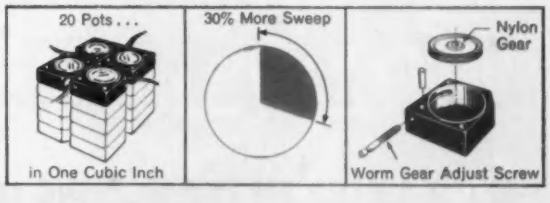
RUGGED, SUBMINIATURE, PRECISION TRIMMERS...

FOR BETTER STACKING . . . exclusive square shape permits stacking as many as 20 pots in one cubic inch.

FOR MORE ACCURATE TRIMMING . . . 30% more turns in resistance element plus 45:1 adjustment ratio provides more accurate trimming than possible with conventional trimmer designs.

FOR MECHANICAL AND THERMAL STABILITY . . . exclusive worm gear adjusting device helps to assure rugged mechanical stability, and unique circular mandrel eliminates expansion-contraction effects for thermal stability.

For full specifications on the complete line of SQUARETRIM potentiometers, contact the Daystrom representative serving your area, or write the factory direct. Ask for Data File CE-1112-1.



DAYSTROM, INCORPORATED
PACIFIC DIVISION
9320 Lincoln Boulevard, Los Angeles 45, Calif.

CIRCLE 71 ON READER SERVICE CARD

These are no sissies!

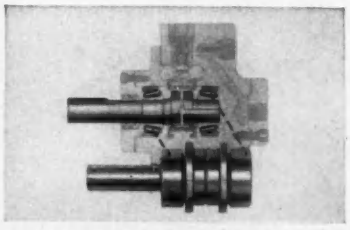
They are AE Hydramite® pumps, the heavy-duty hydraulic pumps that start delivering where other "heavy-duty" pumps leave off. Check into them for the tough jobs where you want sheer stamina...the jobs where extra reliability and sustained performance are an urgent requirement.

To meet your specific requirements, Hydramite pumps can be supplied for constant displacement from 3 to 25 gpm at 5,000 psi and 60 to 100 gpm at 3,000 psi for hydraulic fluids with viscosities of 150 to 300 ssu at 100°F. In special applications they have handled viscosities as low as 40 and as high as 900 ssu at 100°F. Special materials and seals permit handling of missile fuels and special fluids at higher temperatures. Available in flange, foot or face mounted styles.

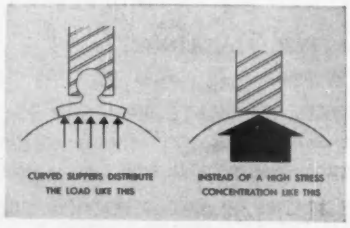
Write or call American Engineering Company, Dept. P-153, Philadelphia 37, Pa. Phone: CUmberland 9-3800.

See our four-page catalog in Sweet's Product Design File, or write us for reprint (Catalog P-60).

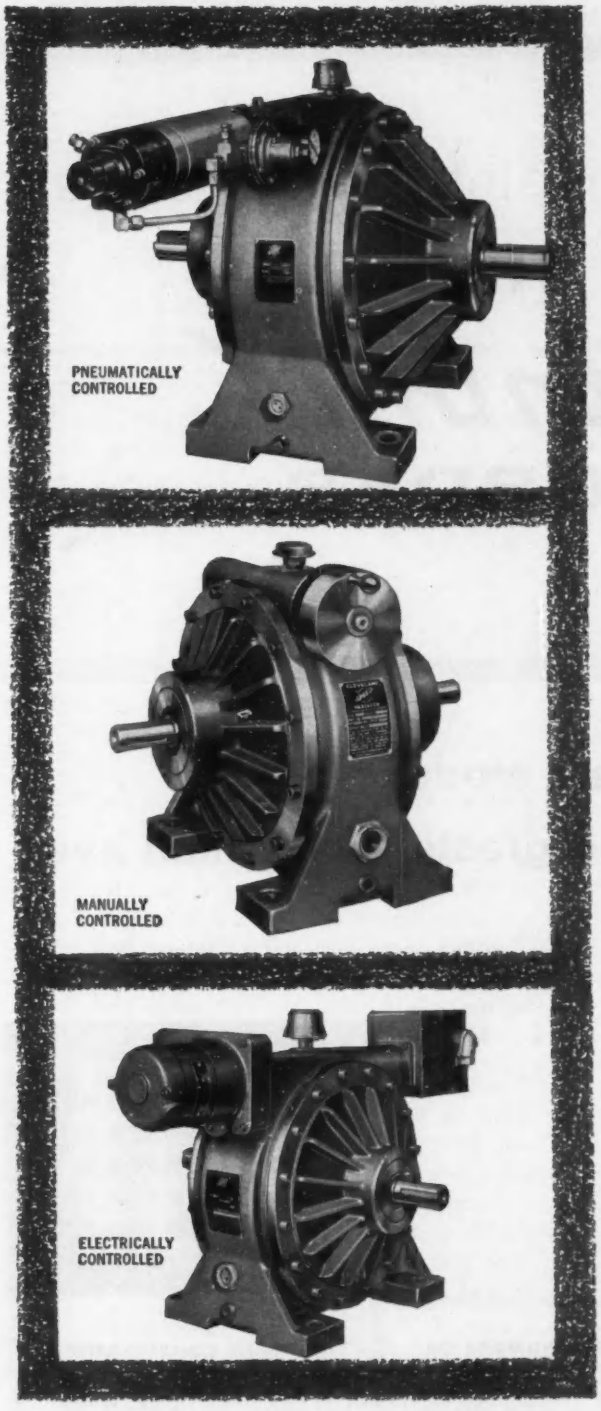
AMERICAN ENGINEERING COMPANY
Division of United Industrial Corporation
Hele-Shaw® Pumps, Lo-Hed Hoists, AE Marine Deck Auxiliaries, Vibra-Grate, Perfect Spread and Taylor Stokers.



Tapered roller bearings. High-capacity, heavy-duty tapered roller bearings support the eccentric cam shaft. This means that a Hydramite can take more punishment . . . handle heavier unbalanced loads . . . and last longer.



Curved Slipper distributes thrust load of the plungers and reduces unit stress to the point where maintenance is never required at what is a critical wear spot in most hydraulic pumps.



with Cleveland Speed Variators... precision control is a simple matter

Cleveland Speed Variators — mechanical traction-type variable drives with stepless speed control — provide both increase and decrease of output speed on a range up to 9:1 from a constant speed power source.

Infinitely variable speed regulation is provided with instant, smooth change by either manual, automatic, or remote control. Precise adjustments are easily made with accurate adherence to settings. Some typical examples:

For the Chemical Industry
In rubber processing seventeen variators provide necessary process flexibility when changing production from one type synthetic rubber to another.

For the Automotive Industry
Variators give accurate control of assembly line speeds to control conveyor output rates.

For the Tobacco Industry
Variators make delicate adjustments for electronic beta gage controller.

For the Steel Industry
Variators provide remote control speed change on processing line conveyor.

For the Metal Working Industry
Variators permit fast, accurate adjustment of machining speeds for metals, from magnesium to 38 Rc steel.

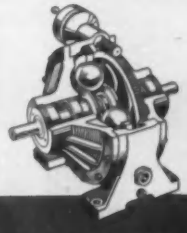
For the Wire Products Industry
Variators control four reels simultaneously — and without slippage.

In Ore Processing
Variators easily adjust rate of material feed to hammermill.

In Material Handling
Variators control movement of steel tubes through 176-roll annealing furnace.

Cleveland Worm & Gear Division
Eaton Manufacturing Company
3260 East 80th Street • Cleveland 4, Ohio

Send for your free copy of Bulletin K-250. It gives the complete Variator control story.

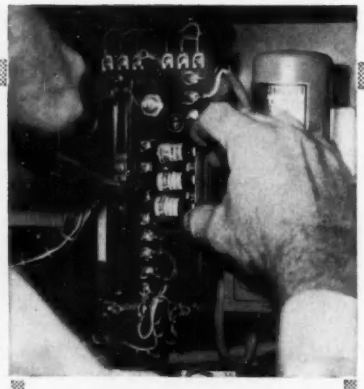


HOW IT WORKS
Power is transmitted from input shaft to output shaft through alloy steel driving balls which are in pressure contact with discs attached to the two shafts. Relative speeds of the shafts are adjusted by changing the positioning of the axles on which the balls rotate (see cutaway view, right).

CLEVELAND SPEED VARIATOR

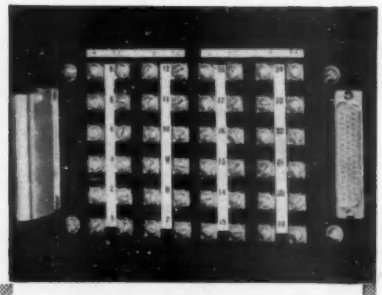
Record 2 to 24 points on the same

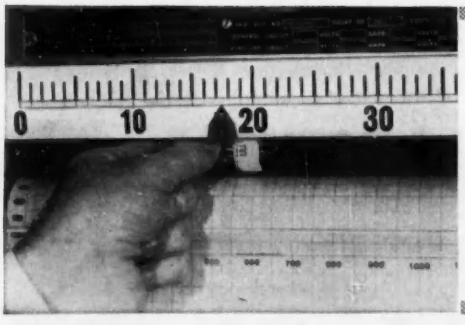
UNIVERSAL *Electronik* RECORDER



CHANGING RANGE IS EASY—Loosen screws and slide out the range resistor card. Replace with a different card, tighten screws and the job is done quickly and easily.

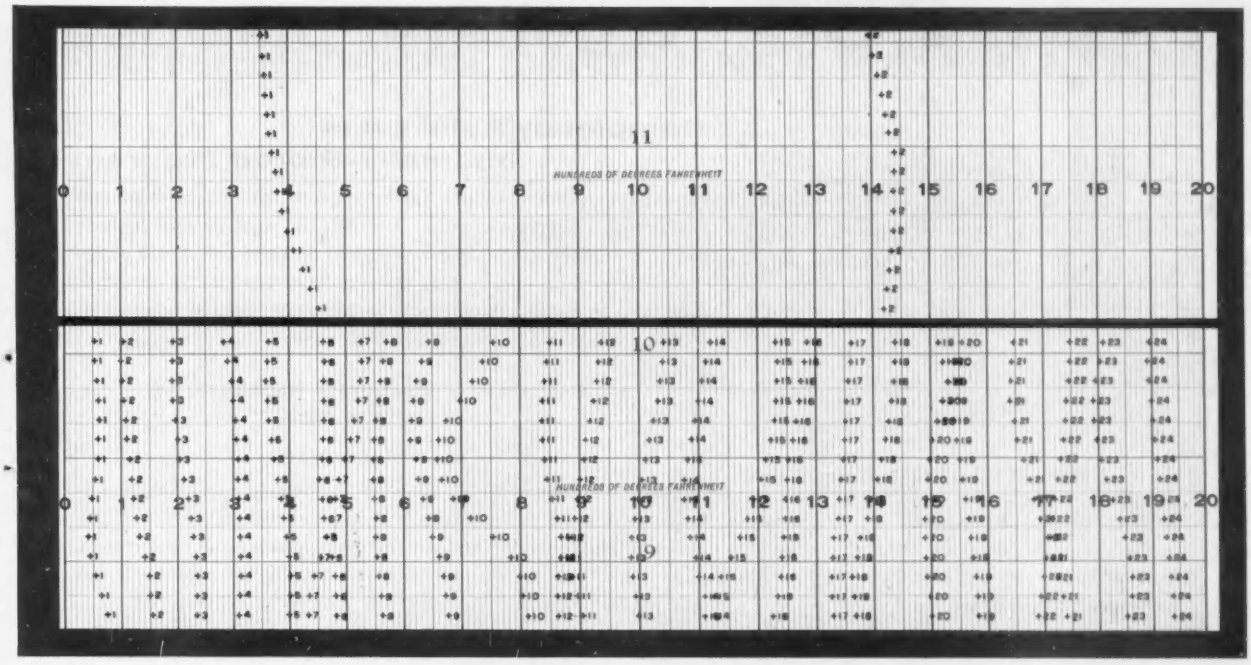
New modular design . . . and greater value than ever





CHANGING NUMBER OF POINTS IS EASY—First, remove thumb-tight nut; slip off print wheel and indicator dial. Slip on new wheel and dial and replace nut. Second, replace one plug-in unit on extreme right of terminal board, and the instrument is ready to record any desired number of points.

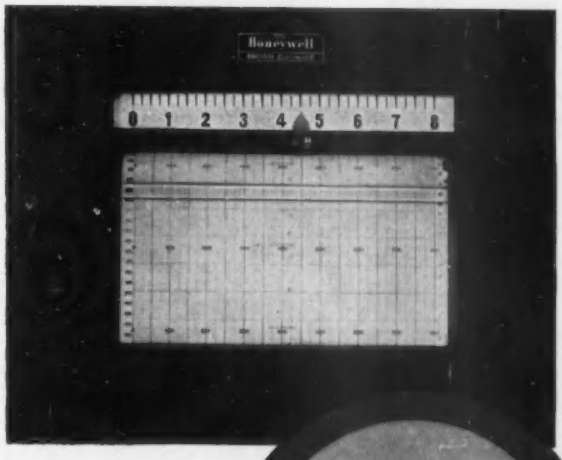
CHANGING COMPENSATION IS EASY—Input terminal board comes out by removing one plug (extreme left) and four screws. Slide in the new board, replace the screws and plug and the compensation is changed. Reference junction is built into terminal board on reverse side.

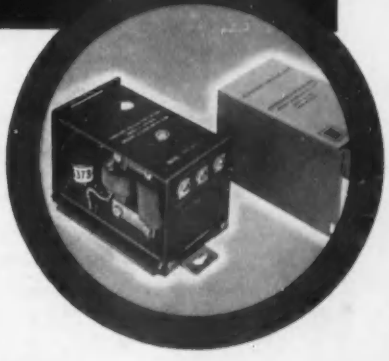


Now, you can record 2,3,4,6,8,10,12,16,20 or 24 points on one instrument—the new Universal *ElectroniK* Recorder. And you can change the number of points to be recorded in a matter of seconds. It's as easy as this: remove a thumb-tight nut and slip off the old print wheel and indicator dial. Slip on a new wheel and dial and replace the nut. Plug in the number of points wanted, and the job is done.

New modular design makes all *ElectroniK* instruments easier to use and maintain and a greater value than ever. This new design has also resulted in substantial manufacturing economies and appropriate price reductions. Get complete details from your nearby Honeywell field engineer. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.





CONSTANT VOLTAGE UNIT (Zener diode) eliminates batteries, standard cells, and standardizing mechanisms.

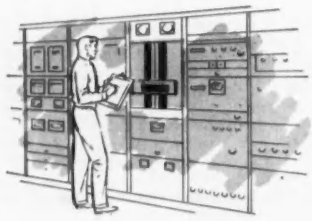
Honeywell

First in Control

SINCE 1885

75th YEAR PIONEERING THE FUTURE

the pb 250 / a general purpose,



The design of the PB 250 enables it to be mounted as a systems component in 31½ in. of a standard relay rack.

SPECIFICATIONS

TYPE
Serial, binary, internal program

COMMAND STRUCTURE
Single address with index register

NUMBER OF COMMANDS
46

OPERATION TIMES

Add/subtract	12 microseconds
Multiply	276 microseconds (max.)
Divide	252 microseconds (max.)
Square root	252 microseconds (max.)
Average access time	1,540 microseconds
Average access time to fast memory	96 microseconds
Maximum operational rate	40,000 instructions per second

WORD LENGTH
21 bits plus sign

MEMORY

Type:
Magnetostrictive delay lines

Capacity:
1,808 words (Up to 15,888 words internal storage at additional cost. 16,384 words external core memory also available.)

INPUT-OUTPUT

Standard:
Automatic alphanumeric typewriter
Paper tape punch and reader
32 control outputs
30 control inputs
High-speed block input-output (85 KC word rate)

Optional:
High-speed paper tape punch and reader
Magnetic tape units (six maximum) employing IBM 700 series format
Punched card equipment
Analog-to-digital converters
Digital-to-analog converters

PHYSICAL DESCRIPTION
30 in. high, 19 in. wide, 24 in. deep
110 pounds
Fully solid-state construction
Completely modularized

POWER REQUIREMENT
115 volts, 60 cycles, at 100 watts

Completely Solid State Internally-Stored Program

From Packard Bell Computer comes the first truly "second-generation" medium-scale computer. The PB 250 is a general purpose digital computer that may be applied to an extremely broad range of scientific, industrial, and military problems. The PB 250 combines a large, expandable memory and a versatile command structure with a computing speed in the microsecond range.

A FEW OUTSTANDING FEATURES OF THE PB 250

MICROSECOND SPEED

Computing speeds of the PB 250 rival those found only in expensive, large-scale systems. Addition and subtraction require 12 microseconds. Multiplication and division are variable length commands requiring 276 and 252 microseconds, maximum, respectively. All floating point operations require less than three milliseconds.

EXPANDABLE MEMORY

Minimum memory capacity of the PB 250 is 1,808 words, including one 16-word fast access line. The memory is economically expandable to 15,888 words internally, plus 16,384 words of external core storage.

VERSATILE COMMAND STRUCTURE

The extensive command list of 46 instructions contains 14 data transfer commands, 8 arithmetic commands (including divide and square root), 14 logical and program transfer commands, and 10 input-output commands.

SIMPLE PROGRAMMING

Programming simplicity is achieved by single-address instructions, command indexing, and automatic double precision operations. Symbolic programming routines are supplied at no extra cost with the PB 250.

FLEXIBLE INPUT-OUTPUT SYSTEM

The PB 250 is adaptable to a wider range of peripheral equipment than any computer in the low-priced field. This equipment includes high-speed tape readers and punches, magnetic tape units, card readers and punches, printers, analog-to-digital and digital-to-analog converters. Standard equipment includes an automatic typewriter, paper tape reader, and punch.

EXCEPTIONAL RELIABILITY

Maximum reliability is achieved through conservative solid-state design, a small component count (less than 350 transistors), and absence of moving parts.

All memory operations are parity checked.

SYSTEMS INTEGRATION

Flexible input-output design enables the PB 250 to be easily integrated into existing systems, either on- or off-line.

The PB 250 may operate as a universal format-to-format converter.

microsecond computer for $30,000

THE
pb 250
will be displayed at the
Western Joint
Computer Conference
May 3, 4, 5
Jack Tar Hotel
San Francisco, booth 17

PACKARD BELL COMPUTER

A Subsidiary of
Packard Bell Electronics

1905 ARMACOST AVENUE, LOS ANGELES 25, CALIFORNIA • GRANITE 8-4247

TO REACH THE MOON... MEN AT WORK

These men are ARMA researchers. They are putting to use a three-dimensional Trajectory Analyzer, designed and produced by them to provide simple, visual understanding of the complexities involved in guiding missiles to interplanetary bodies.

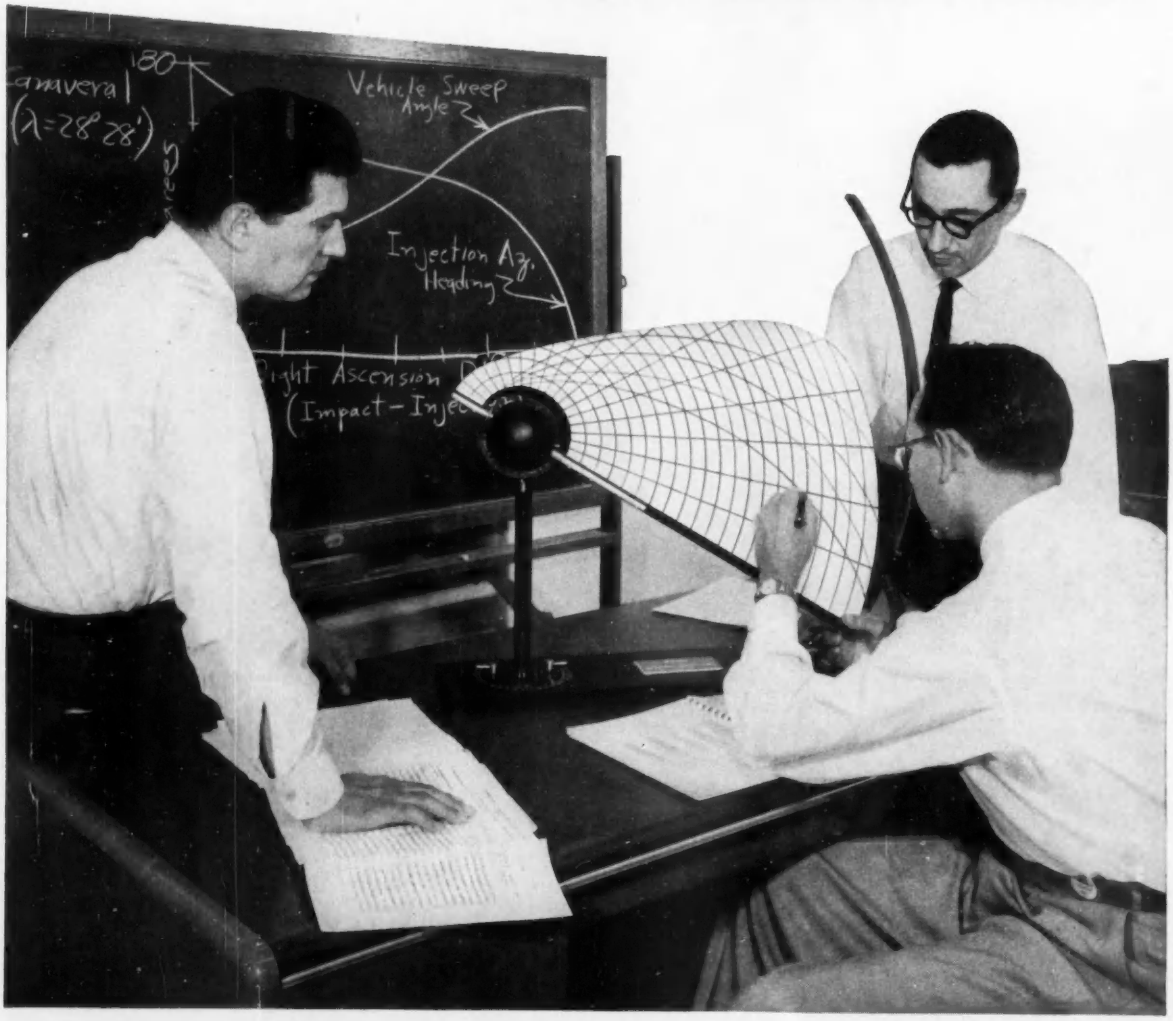
Today they use it in their studies of trajectory kinematics and missile guidance in lunar orbits. Sometime soon they will employ it to study travel to other bodies.

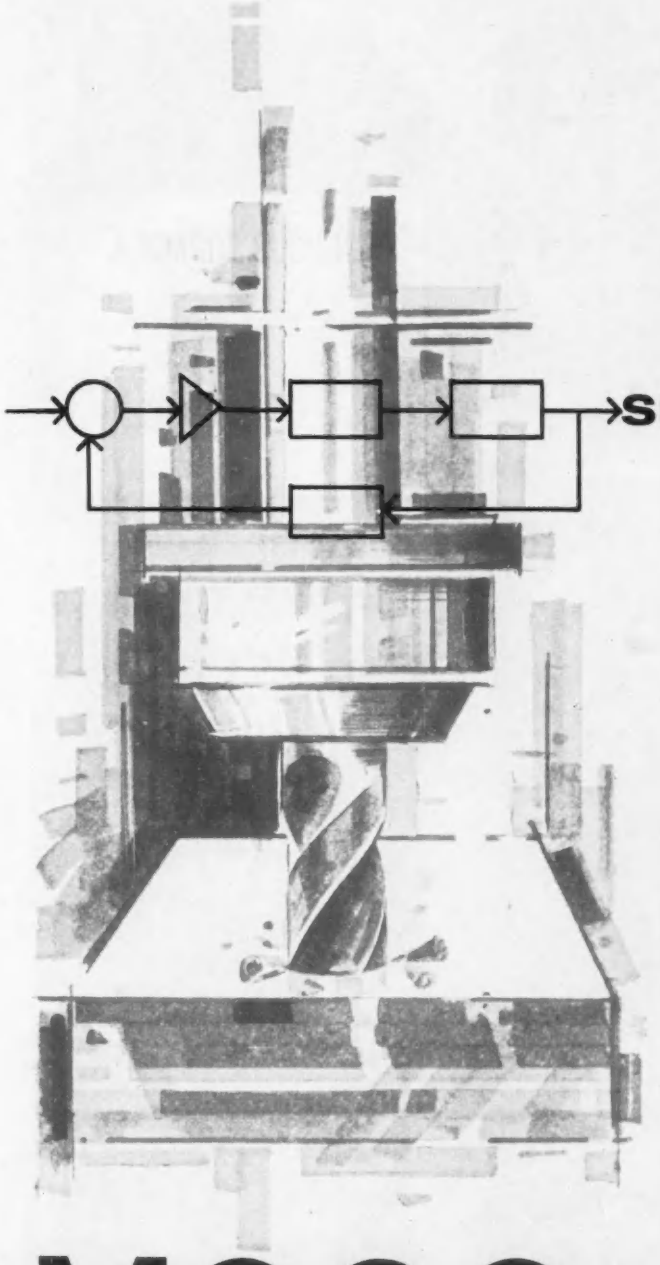
The Trajectory Analyzer—with which the trajectory of any computer-simulated or real missile can quickly be plotted *in grease pencil*—demonstrates the ingenuity and analytical ability of ARMA's imaginative research staff, creators of the Atlas ICBM inertial guidance system. Their experience and performance are unequalled in the broad field of space navigation.

ARMA, because of its *people*, will find many of the answers in astronautics. ARMA, Garden City, N.Y., a division of American Bosch Arma Corporation . . . the future is our business.

7408

AMERICAN BOSCH ARMA CORPORATION





electrohydraulically speaking...

how accurate, how reliable is a SERVOSYSTEM?

The servovalve is the prime determining factor of reliability and accuracy in a Servoactuation system. In a drive control system which includes servovalves, amplifiers, actuators and necessary power supplies, exceptional valve performance is required. Use of Moog's servovalve and unitized approach to system design insures maximum component performance.

SERIES 71 SERVOVALVE

SERIES 72 SERVOVALVE

comparatively speaking . . .

WHAT ADVANTAGES DO ELECTROHYDRAULIC SERVOSYSTEMS OFFER?

". . . First and foremost, they provide dynamic response capabilities completely out of the range of any other types of control . . . Their range of dynamic response is much higher than the fastest pneumatic system . . .
The next important advantage offered is size and weight . . . the complete hydraulic system for all but the very low horsepower applications is lighter than any other type of powered control system . . .
Third, the systems are rugged. They can operate under severe environmental conditons."*

*Bernard A. Johnson NCIH Article 13th Annual Meeting
"The Application of Electro-hydraulic Servo Valves to Industrial Control"

MOOG:

SERVOSYSTEMS IN INDUSTRY

WRITE FOR PB110

MOOG SERVOCONTROLS, INC. INDUSTRIAL DIVISION EAST AURORA, N. Y.

Enter an x value into the Monro-Matic Statistical Calculator keyboard only once; the machine takes over the squaring; automatically, your task is nearly halved.

This is one of many advanced features especially pleasing to people who live with figures. Why not ask your Man from Monroe for a free demonstration of the Monro-Matic Statistical Calculator today?

MONROE

for CALCULATING
ADDING • ACCOUNTING
DATA PROCESSING MACHINES

A DIVISION OF LITTON INDUSTRIES

Monroe Calculating Machine Company, Inc., Sales and service in principal cities everywhere. General offices, Orange, N. J.

GD700 SERIES
GAS-O-DOME REGULATORS

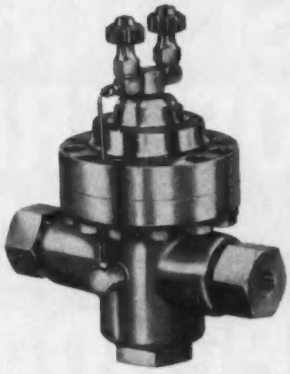
Models in bronze or stainless steel
Pilot operated type
Max. inlet: 7000 to 10,000 psig.
Outlet range: 10-150 to 400-7000 psig.
Flows to 250 scfm.
Low torque: 35 inch-lb. at 7000 psig.
Panel mounting
Bulletins R12 and R18.

BPR SERIES
BACK PRESSURE REGULATORS

Models in bronze or stainless steel
Adjustable relief ranges: From 25-500 psig. to 2000-10,000 psig.
Panel mounting
Bulletin R19

LR SERIES LOADER REGULATORS

Models in bronze or stainless steel
Max. inlet: 7000 to 10,000 psig.
Outlet range: 5-200 to 200-10,000 psig.
Flow: 10 scfm.
Low torque: 35 inch-lb. at 7,000 psig.
60 inch-lb. at 10,000 psig.
Panel mounting
Bulletins R11 and R17



GD90, GD100A AND GD200A
SERIES GAS-O-DOME REGULATORS

Models in bronze or stainless steel
Compensated, high-flow type
Max. inlet and outlet: 6000 psig.
Flows to 80,000 scfm.
Remote control and/or
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LV-10 LOADER VALVE

Made in bronze only.
Inlet and outlet: 7000 psig.
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GAS-O-DOME REGULATORS

Models in bronze
(stainless steel on request)
Inlet and outlet range: 2500 to 10,000 psig.
Flows to 1500 scfm.
Remote control and/or
panel mounting provisions
Bulletin R10A

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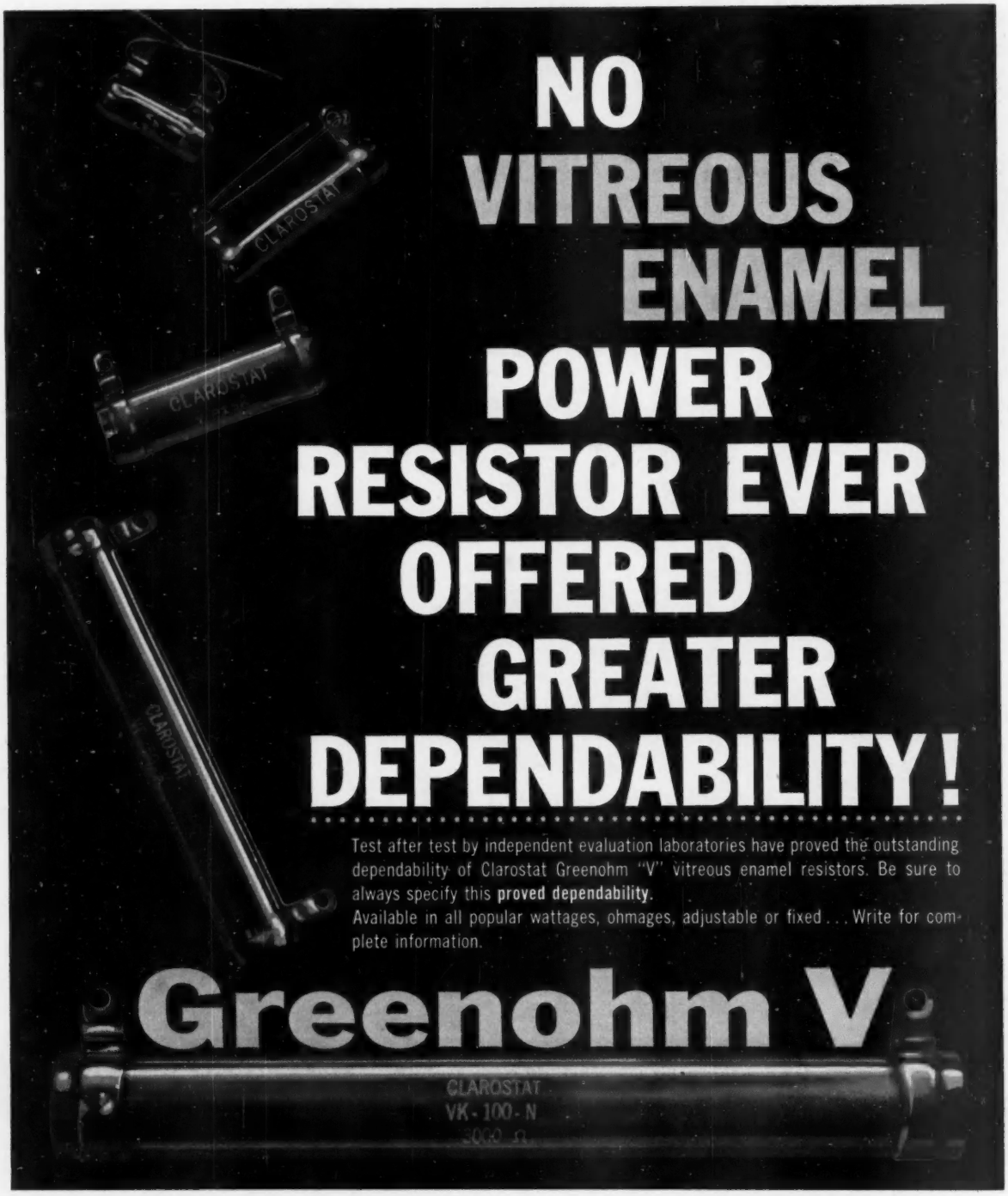

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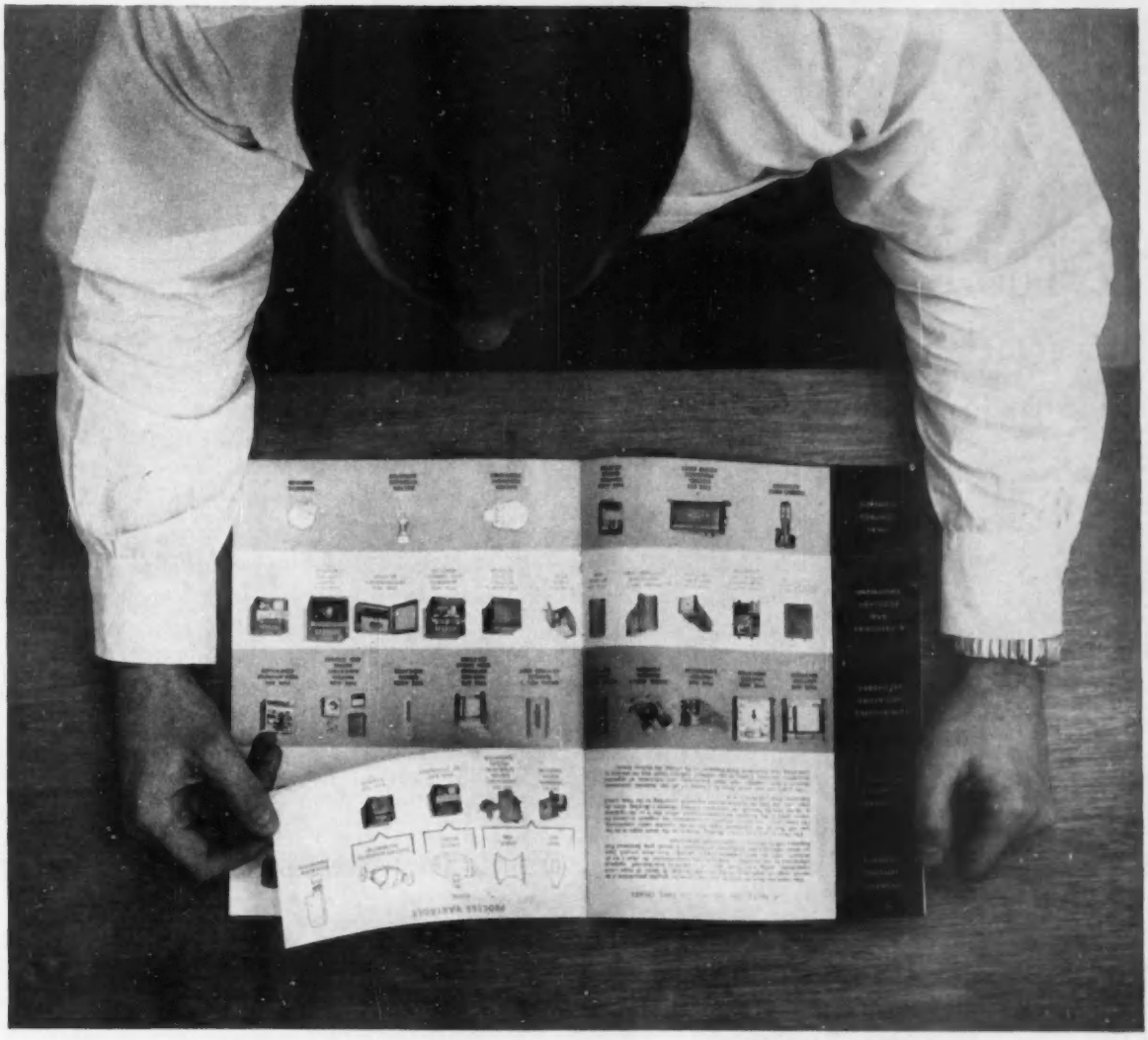

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At The Ramo-Wooldridge Laboratories... integrated programs of research & development of electronic systems and components.

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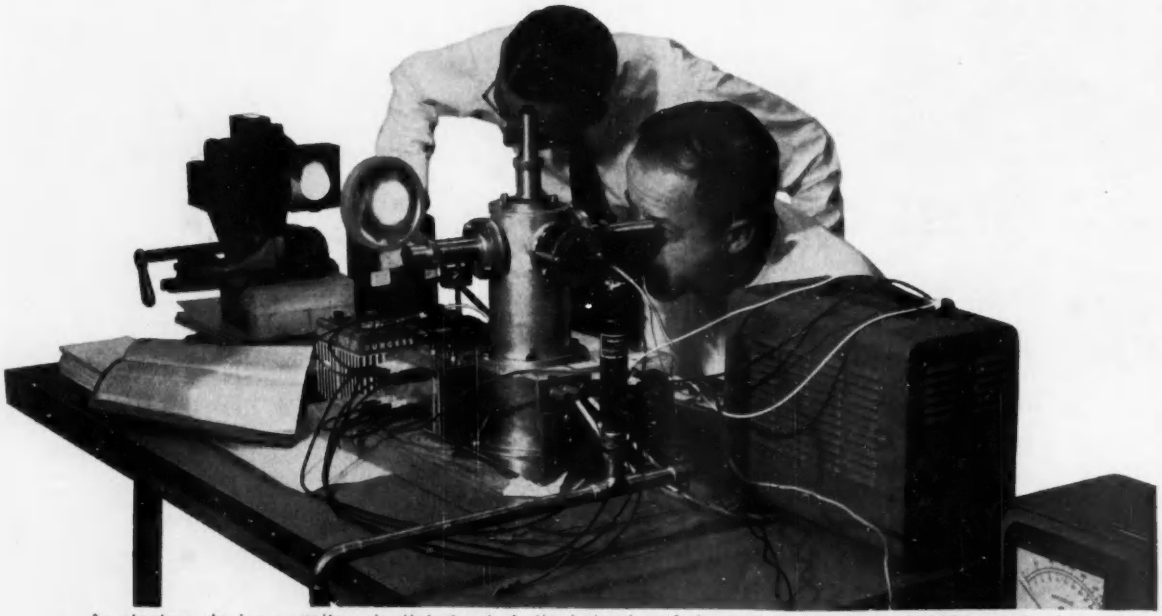
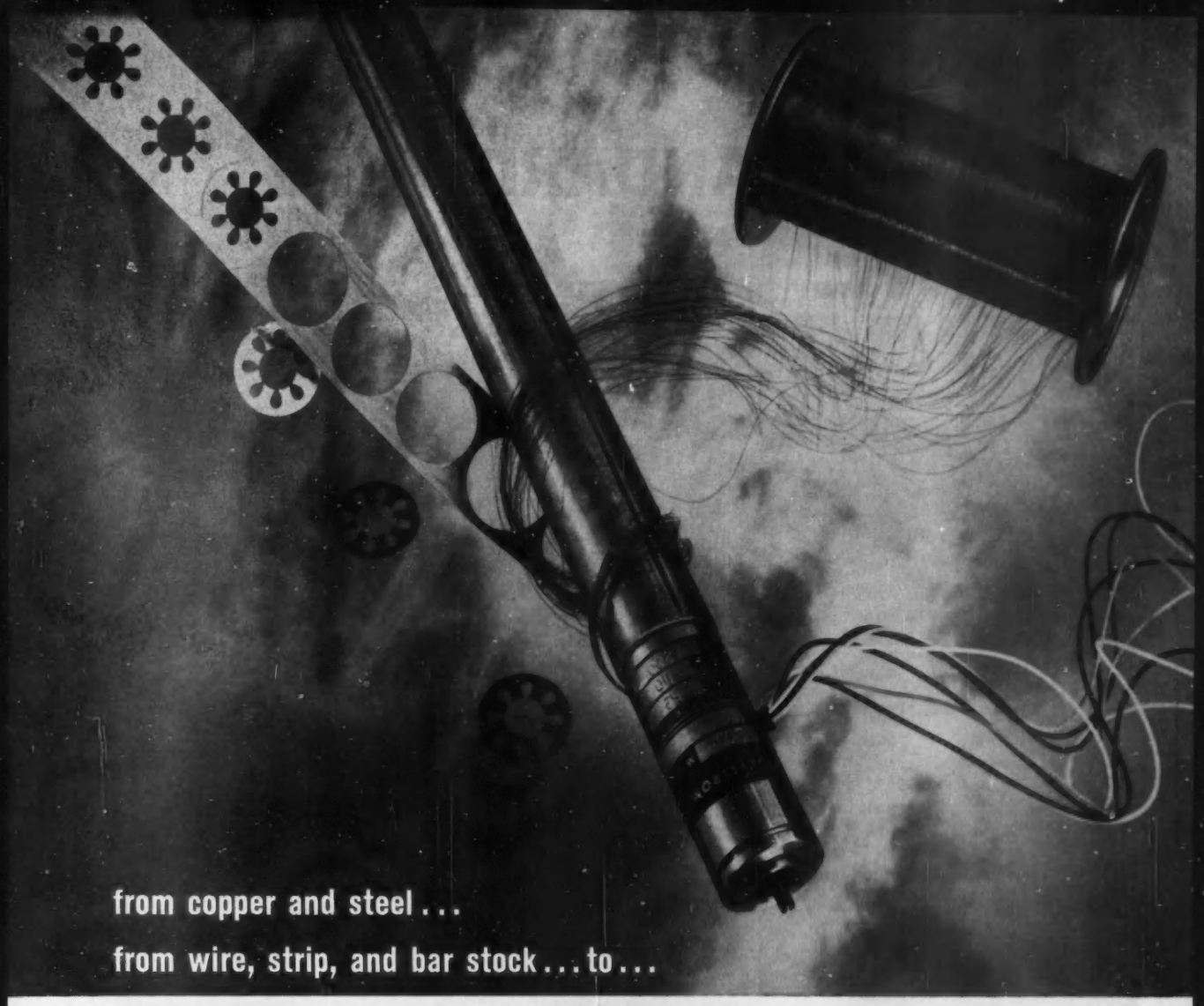


An electron device permits scientists to study the behavior of charged dust particles held in suspension.



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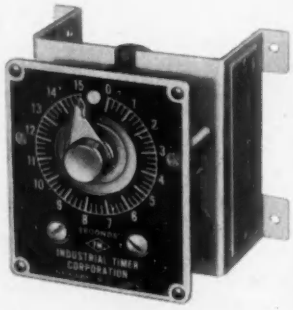
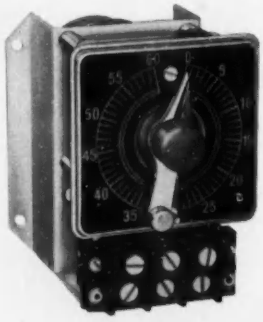
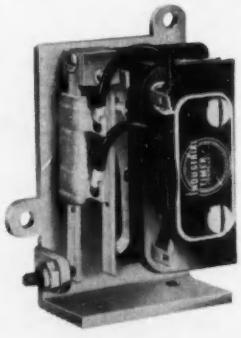


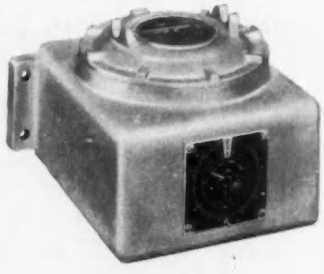
Series SF
Back-mounted (1/10 sec. to 5 min.)



Series TDAB
Flush-, back-mounted or totally enclosed (1/60 sec. to 3 hrs.)



Series TH
Back or bottom-mounted. Thermal time delay switch. (15 sec. to 2 min.)



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NUMBER 5—RELIABILITY SERIES

Plunging a potentiometer into near-boiling water is just one of the ways Bourns puts the proof in humidity-proof. Every Trimpot unit made takes this 60-second bath with the water simmering at 90°C. Air expanded by the heat creates four pounds of pressure inside the potentiometer—enough to cause bubbles—if it leaks. Only if the unit is completely leak-free does it pass the test.

Bourns humidity proofing starts at the beginning—with original design and selection of materials. The plastic chosen for Trimpot cases, for example, displays the unusual properties of high insulation resistance and extremely low moisture absorption.

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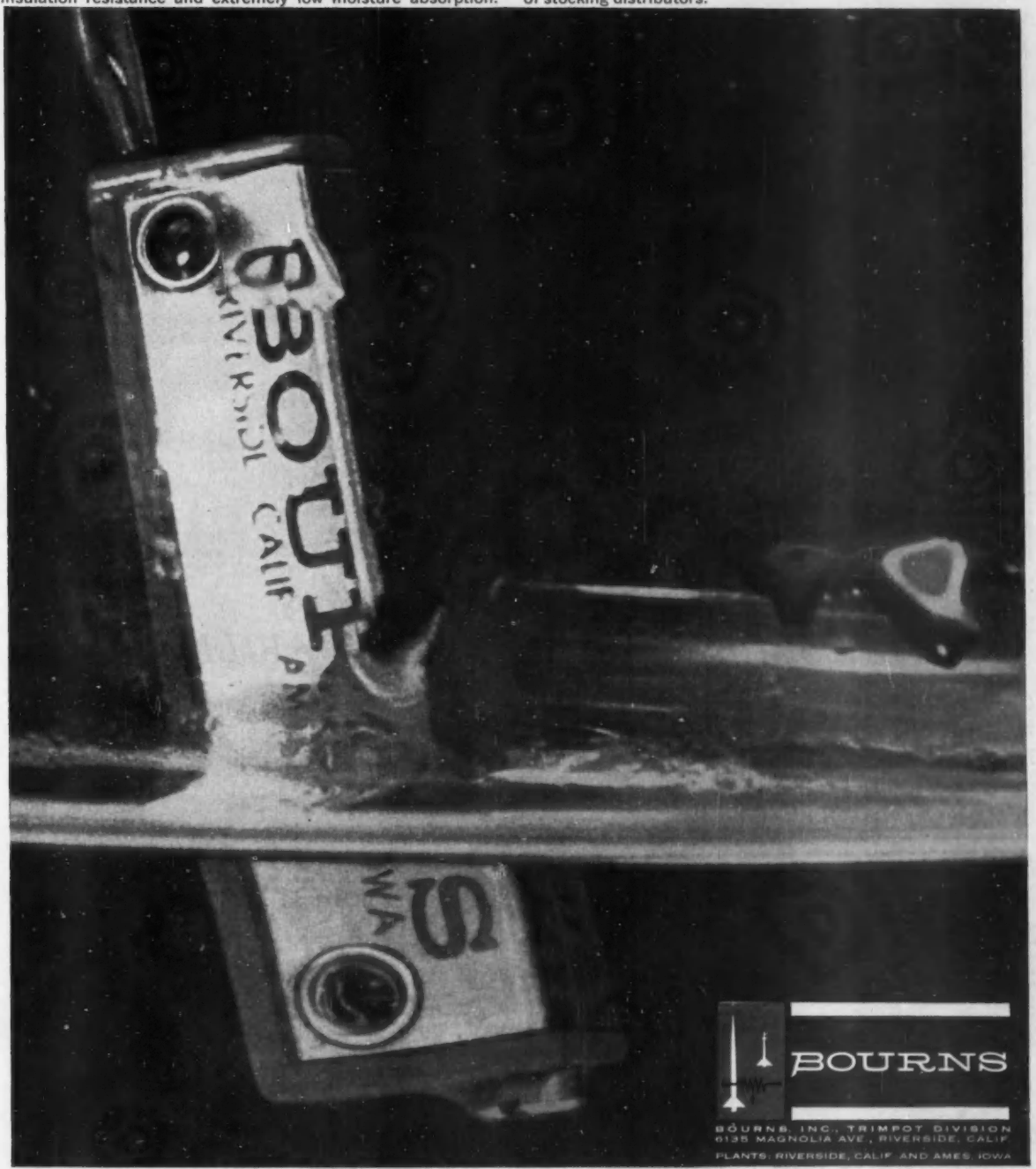
For more information about the industry's largest selection of humidity-proof adjustment potentiometers—wirewound and carbon in a variety of sizes, power ratings, operating temperatures, etc.—write for new Trimpot summary brochure and list of stocking distributors.



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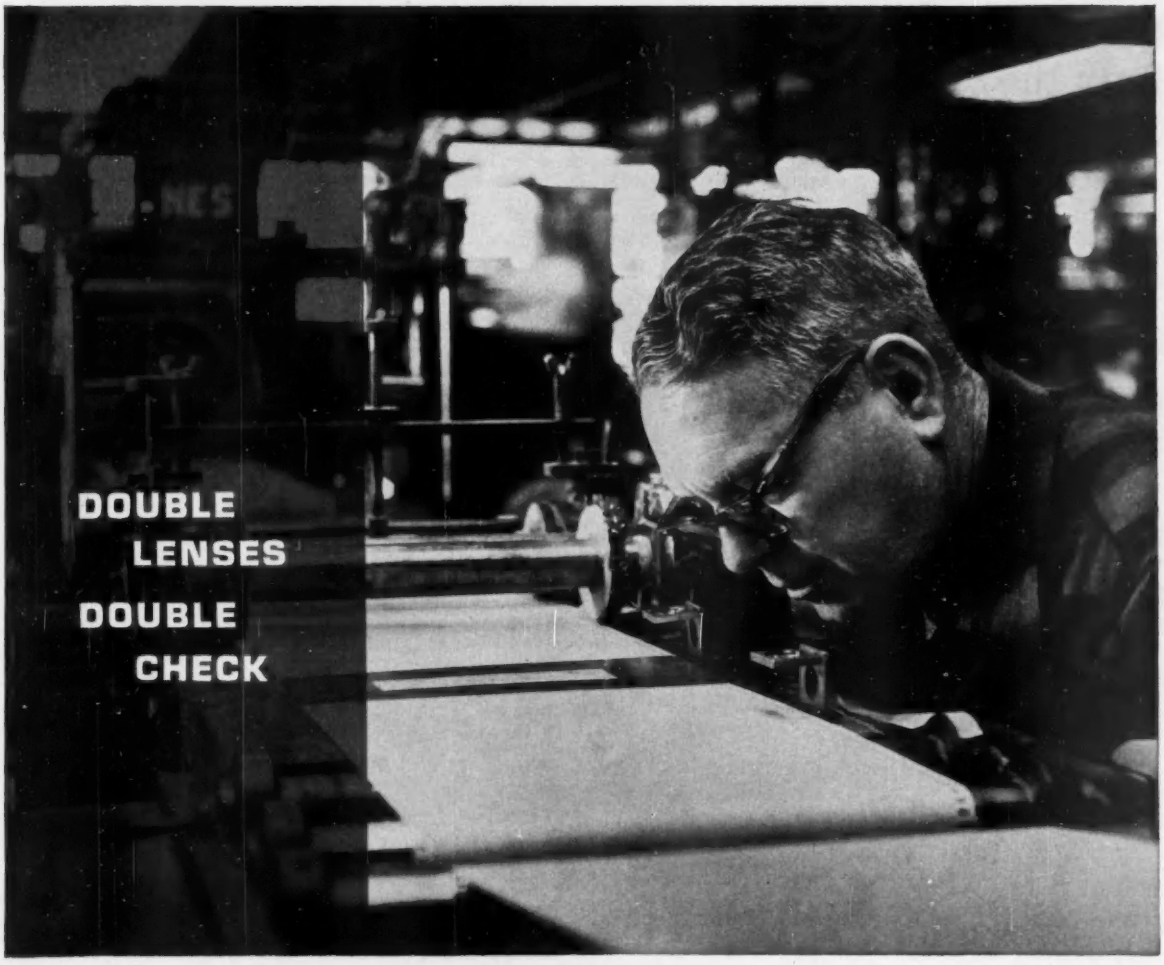

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Charlie Robinson, our pressroom supervisor, is making a careful chart calibration check in the picture above. He does this often.

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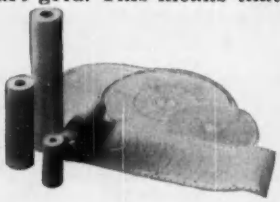

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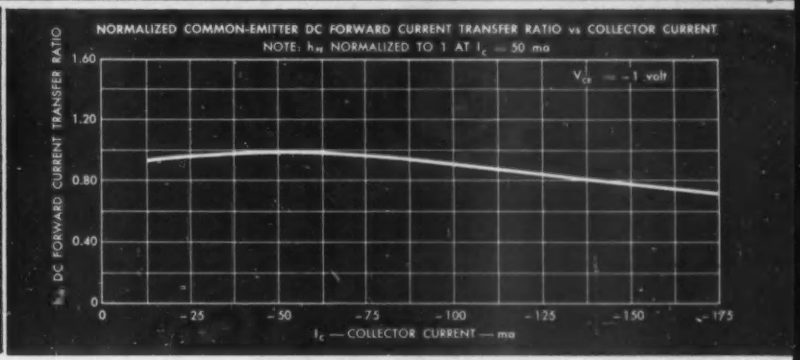
TI low cost germanium general purpose transistors give you 250 mw dissipation

...with beta spreads as low as 2:1



Available in commercial production quantities, TI 2N1372 series germanium P-N-P alloy transistors make possible low-cost applications that provide linear beta, high power gain and low distortion characteristics. These general purpose economy transistors are especially suited for your medium frequency switching circuits, audio amplifiers and motor control applications.

Fully automatic testing and classification by CAT (Continuous Automatic Testing) completely eliminates human error and assures uniformity and reliability... ideal for your production assembly and testing requirements.

Evaluate the specifications below and contact your nearby TI distributor or TI sales office for the devices most suited to your particular requirements.

maximum ratings at 25° C ambient		**2N1372**	**2N1373**	**2N1374**	**2N1375**	**2N1376**	**2N1377**	**2N1378**	**2N1379**	**2N1380**	**2N1381**	**Unit**
Collector—Base Voltage		−25	−45	−25	−45	−25	−45	−12	−25	−12	−25	v
Collector Current		−200	−200	−200	−200	−200	−200	−200	−200	−200	−200	ma
Total Device Dissipation		250	250	250	250	250	250	250	250	250	250	mw
Storage Temperature Range						−55 to +100						°C
electrical characteristics at 25° C ambient												
I_{CBO} Collector Reverse Current												
(V_{CB} = −12v I_E = 0)	(max)							−7		−14		μa
(V_{CB} = −20v I_E = 0)	(max)	−7	−7	−7	−7	−7	−7		−7		−14	μa
(V_{CB} = −1.5v I_E = 0)	(typ)	−3	−3	−3	−3	−3	−3	−3	−3	−3	−3	μa
h_{FE} dc Forward Current Transfer Ratio*	(min)	30	30	50	50	75	75	95	95	30	30	
(V_{CE} = −1v I_C = −50 ma)	(typ)	45	45	80	80	95	95	200	200	100	100	
	(max)	95	95	150	150	150	150	300	300	300	300	
$f_{\alpha b}$ Common-Base Alpha-Cutoff Frequency (V_{CB} = −5v I_C = −1 ma)	(typ)	1.5	1.5	2	2	2	2	3	3	2	2	mc
Noise Figure 1000 cps†	(typ)	7.0	7.0	6.5	6.5	5.5	5.5	4	4	5.5	5.5	db

*Tolerance on all values ±10% for test set correlation. †Conventional noise compared to 1000 cps and 1 cycle bandwidth.

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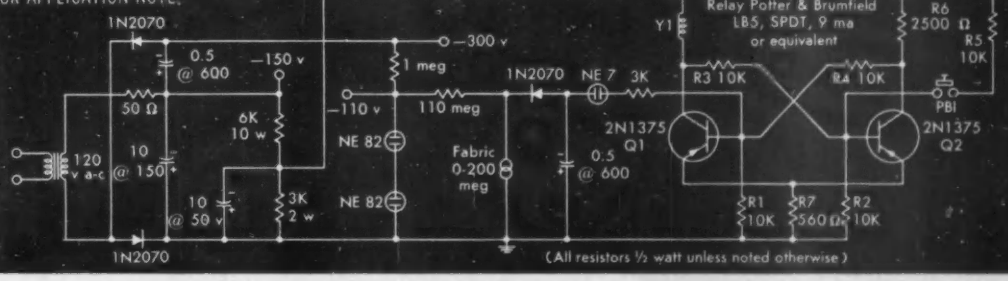
High Resistance Sensing Unit



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CIRCLE 89 ON READER SERVICE CARD

That Amazing Semiconductor Business

For rapid growth, the semiconductor business threatens to smash every record in the book. Executives of the 90 companies that shared the $400 million market last year will remain gasping for breath to keep pace with the rapid technological changes. *Business Week* magazine, for example, predicts that the semiconductor market will top $1 billion by 1963. When you consider that the first commercial transistor appeared only nine years ago, such sales growth has to be called phenomenal; it illustrates what can happen to an industry when technological progress has almost free rein.

No letup

At the IRE Show in March, manufacturers of semiconductor devices showed that there is no letup in technological advance in sight. New semiconductor developments abounded on every side. Eight companies displayed prototype tunnel diodes, the highly publicized high frequency amplifying device; at least three showed or talked about developments in molecular electronics; and practically every supplier of diodes and transistors was offering an improved device that could boast better performance characteristics, smaller size, or lower price.

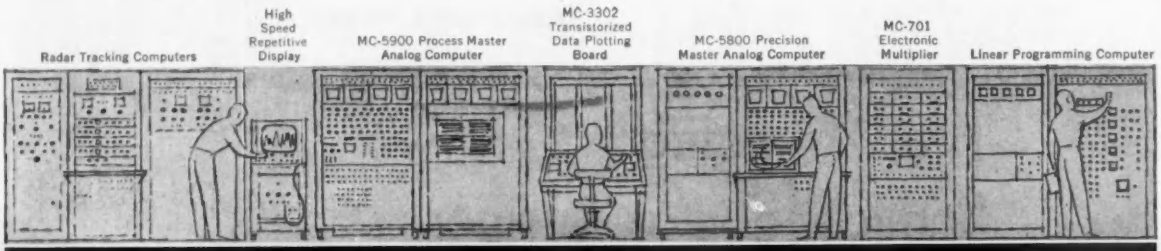
Current kingpin of the semiconductor business is fast-growing Texas Instruments which has changed from a company with $7 million a year sales in 1947, mostly geophysical instruments and services, to a $163 million Goliath in 1959, the bulk of the gain coming from the newly founded semiconductor business. TI's booth at the IRE Show typifies the revolution in semiconductors; in addition to several better performing transistors, TI exhibited:

- first *commercially available* gallium arsenide tunnel diodes. The four units on display were designed for applications in high speed circuitry such as logic circuits, amplifiers, and oscillators.
- first *commercially available* solid circuit semiconductor network. The device, made of a single silicon crystal, is a binary multivibrator capable of operation at a 200 kc repetition rate. It contains the equivalent of 16 conventional components. Size of the standard unit: only 0.250 x 0.125 x 0.031 in.
- a line of silicon transistors designed specifically for industrial applications. The new units: grown junction general purpose and medium power transistors and NOR logic devices. For the latter, TI is packaging seven transistors in a kit, each kit is a complete logic system.

TI apparently stole a march on the industry by offering commercial availability of the tunnel diode at the distributor level. Previously both RCA, GE, and Sylvania had made samples of Esaki diodes available. At the show, Philco Corp. was the latest supplier to offer a tunnel diode prototype.

Molecular electronics

TI's standard semiconductor network illustrates another area of frantic activity in the frantic semiconductor field. Texas Instruments is said to have over 200 engineers and scientists working on functional, one-piece semiconductor systems. At the technical sessions Col. W. S. Heavner, chief, Electronic Technology Laboratory, Wright Air Development Div., again warned that molecular electronic devices threaten the markets of conventional electronic components (his earlier warning was reported in CtE, March 1960, p. 35). Heavner predicted that this will happen much sooner than most people expect. He said he expected TI to complete a simple molecularized computer by 1961 and Westinghouse to build a VHF receiver by 1962.



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solving problems hitherto unsolvable

DYSTAC (Dynamic Storage Analog Computer) synthesizes the advantages of both analog and digital computers. DYSTAC combines the analog's speed, lower cost, ease of programming, and improved output data presentation with the digital computer's unique capacity for data storage and time sharing of computer elements. With DYSTAC you can now solve the most complex problems, ranging from distillation column design to multi-dimensional heat transfer... from boundary value problems to transport lags.

In distillation column design, for example, DYSTAC employs only 44 amplifiers on a four-component problem; the number of amplifiers required is independent of the number of plates. With any other analog computer each plate must be reproduced in the circuitry—for a 30-plate column, over 1200 amplifiers are needed unless manual reprogramming is employed. What's more, only DYSTAC yields a plate-by-plate display of all column conditions.

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When you buy a CSI computer with DYSTAC you are buying more than the finest general purpose analog computer. You buy additional capacity as well as capability. For when DYSTAC elements are not in use as memory devices they are available to the computer as operational amplifiers. Planning to interconnect digital and analog computers? DYSTAC is the answer.

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At another technical session, a representative of Varo Mfg. Co. described an unusual technique his company developed to form a number of semiconductor devices in a single substrata of single crystal silicon. Other companies working in this area: RCA and Motorola.

Today's devices

But not every semiconductor device supplier has hitched its wagon to the sensational aspects of the semiconductor field. A lot of them are interested in supplying the components to "build the equipment which has been already designed and which will be sold next year."

That's the way David Bakalar expressed what his company, Transitron Electronic Corp., will do. Transitron is another of the Cinderella electronics companies; it has jumped in five years from sales of practically nothing to estimated 1960 sales of $50 million.

Transitron, which will spend $5 million on semiconductor research in 1960, is directing some of its biggest research efforts at miniaturizing conventional semiconductor devices. At the IRE show the company introduced a miniature diode no bigger than a quarter of a dried pea. Transitron, says Bakalar, hopes to introduce a miniaturized transistor later this year. He said the semiconductor and electrical portion of development was solved; the big problem, it turns out, is packaging. Other Transitron new products: the first high temperature, radiation resistant, silicon carbide rectifier to replace silicon rectifiers in high temperature applications (up to 500 deg C) and a line of PNPN controlled rectifiers (also known as the silicon controlled rectifier).

Tomorrow's packages

The packaging problem has semiconductor companies trying a variety of new techniques. Pacific Semiconductors Div. of Thompson Ramo Wooldridge, Inc., for example, is using an oxide process to eliminate the metal case. The company is already selling diodes with such a package, has built a prototype mesa transistor the size of a pinhead with oxide coating instead of a metal can. Motorola is experimenting with a glass package.

For its specialization, Fairchild Semiconductor Corp. has chosen to push the mesa transistor, a diffused base device that can be made with far better control than previous types of transistors. Motorola is planning a big push on this type of transistor, too. Delco-Remy Div. of General Motors, not surprisingly, is gearing its semiconductor work to automotive applications. The bulk of Delco-Remy's production to date has gone for transistorized car radios. But the company is now talking about semiconductor ignition systems. Sylvania Electric Products, Inc., supplier of the broadest line of transistors available to industry, is aiming at high frequency applications, sees an increasing need for components operating in the microwave region.

Impact on control

At this stage of the game, nobody is in a position to tell exactly how much of their semiconductor production is going into measurement and control applications. But makers will tell you that such applications give them their biggest headaches because performance requirements are stricter. With today's production techniques, most companies don't know what types of transistors they are making until they inspect them. High frequency transistors command the highest prices.

Prices of transistors are a tricky thing to keep track of because they change so rapidly. As an example, when Philco introduced a high performance switching transistor in 1956, samples cost $100 a piece. The device was first marketed commercially in 1957 at a cost of $60 per unit; the price dropped to $19 three months later and now sells for $6.75 each in lots of 1,000.

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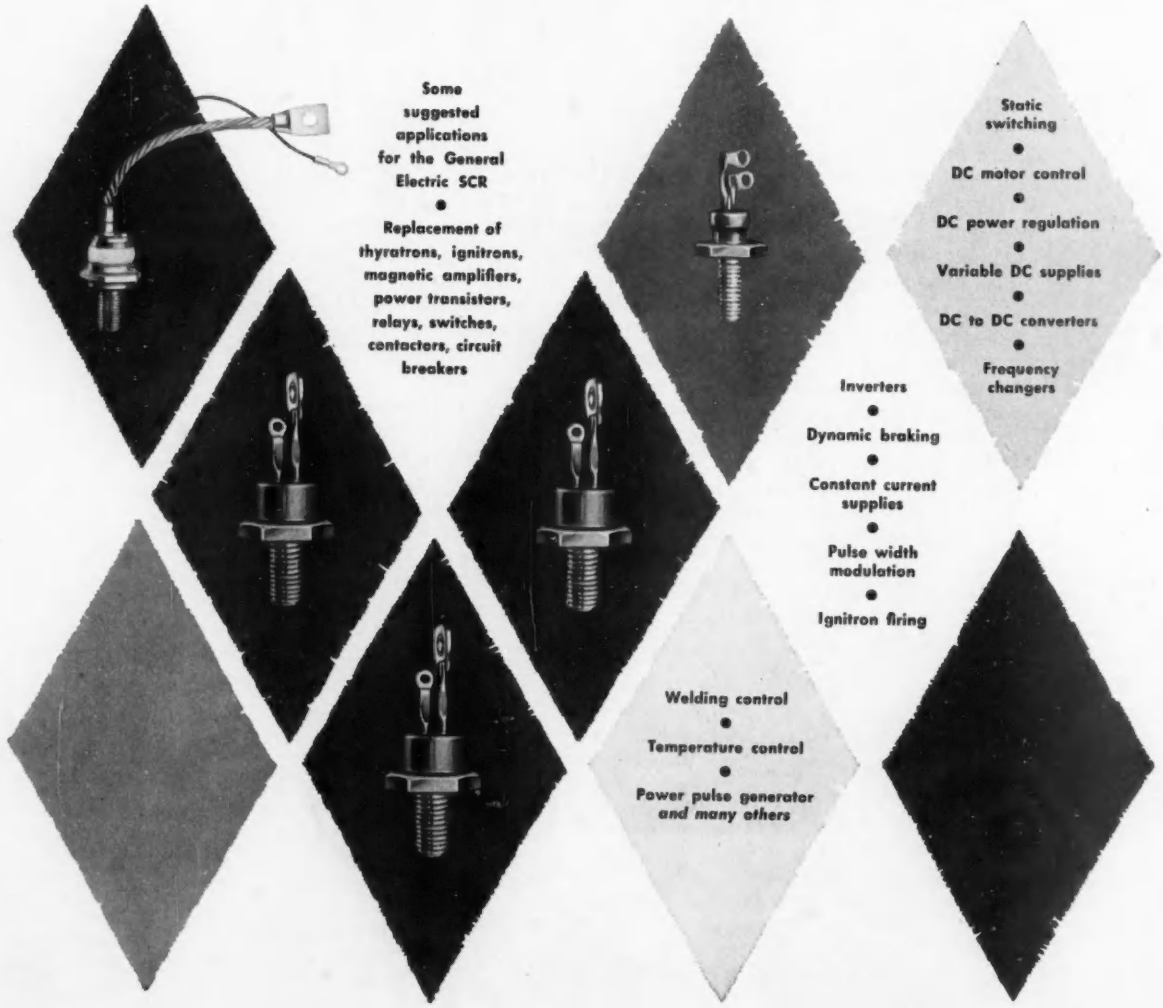

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Since its introduction in 1957 by General Electric, hundreds of firms have successfully incorporated G-E Silicon Controlled Rectifiers into their products. The impact of this revolutionary device that not only rectifies but controls current is growing every day. Volume production of a wide range of SCR types is now a reality at General Electric.

G.E.'s medium-current C35 Series provides blocking voltages to 400 volts and load currents to 16 amperes. The high-current C60 Series goes to 300 volts and 50 amperes; low-current C10 Series 400 volts and 4 amperes. The C40 Series has ratings identical to C35, but is specially selected to furnish guaranteed fast turn-off time for inverter circuits. The C36 Series has ratings lower than C35, with currents up to 10 amperes. The C60 features an all hard-solder design for a high degree of freedom from thermal fatigue.

New SCR Application Manual presents all significant design information developed to date and many new circuits. Your G-E Semiconductor Sales Representative also has complete application data. Many authorized G-E Distributors now stock Silicon Controlled Rectifiers for fast delivery at factory prices in quantities up to 100.

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General Electric Company, Semiconductor Products Dept., Electronics Park, Syracuse, N. Y. In Canada: Canadian General Electric Co., 189 Dufferin St., Toronto, Ont., Export: International General Electric Co., 150 East 42nd St., N. Y. 17, N. Y.

Maximum Allowable Ratings*	C10 Series (8 types)	C35 Series (8 types)	C40 Series (5 types)	C36 Series (8 types)	C60 Series (7 types)	
Continuous Peak Inverse Voltage (PIV) and Minimum Forward Breakover Voltage (V_{BO})	25-400	25-400	100-300	25-400	25-300	Volts
Transient Peak Inverse Voltage (non-recurrent <5 millisecond)	35-500	35-500	35-500	35-500	35-400	Volts
Average Forward Current, Single Phase (up to)	4.7 @ 60°C Stud	16 @ 65°C Stud	16 @ 65°C Stud	10 @ 43°C Stud	50 @ 87°C Stud	Amperes
Peak One Cycle Surge Current	60	150	150	125	1000	Amperes
Operating Temperature	−65°C to +150°C	−65°C to +125°C	−65°C to +125°C	−40°C to +100°C	−65°C to +150°C	
Characteristics At Maximum Ratings						
Maximum Forward Voltage (full cycle Avg.) at Maximum Forward Current	0.75	0.86	0.86	1.25	0.75	Volts
Maximum Gate Current to Fire (I_{GF})	6	25	25	50	50	ma
Maximum Gate Voltage to Fire (V_{GF})	2	3	3	3.5	3.5	Volts
Maximum Thermal Resistance (R_T)	3.1°	2°	2°	2.5°	0.7°	°C/watt Junction to Stud

*Ratings shown are from the lowest to the highest rated types within the series.

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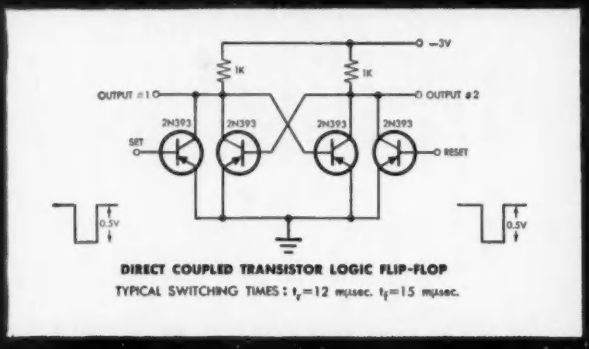
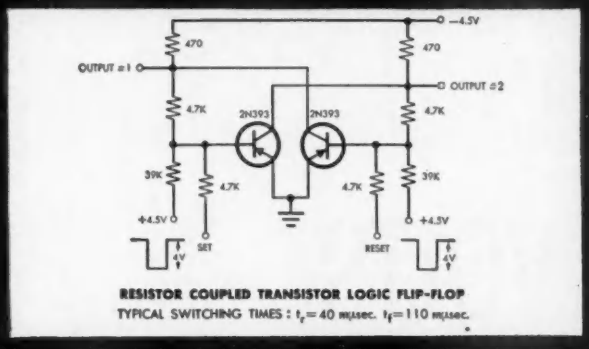
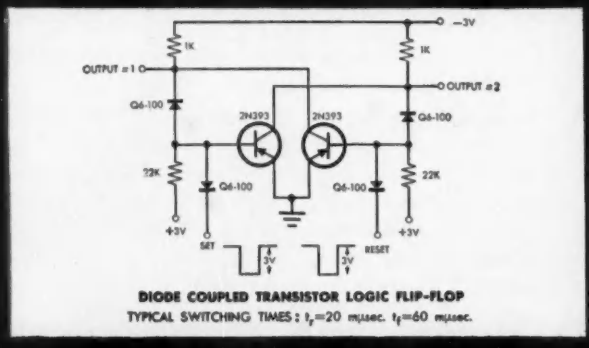


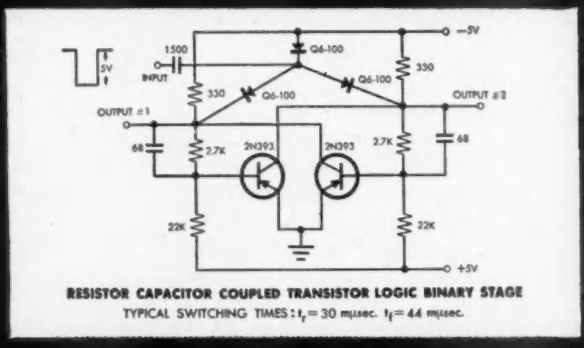
DIRECT COUPLED TRANSISTOR LOGIC FLIP-FLOP
TYPICAL SWITCHING TIMES: t_r=12 m/sec. t_f=15 m/sec.



RESISTOR COUPLED TRANSISTOR LOGIC FLIP-FLOP
TYPICAL SWITCHING TIMES: t_r=40 m/sec. t_f=110 m/sec.



DIODE COUPLED TRANSISTOR LOGIC FLIP-FLOP
TYPICAL SWITCHING TIMES: t_r=20 m/sec. t_f=60 m/sec.



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An Experiment in Ethics

After attending just about any technical meeting have you been as concerned as we over the free-for-all conduct of business? You're drawn to the meeting by the expectation that you'll get some technical updating, swap some know-how, and see the latest products. If you represent commercial opportunity for vendors, you expect that they'll want to show you their wares. If you're blessed with skills that are in urgent demand, you won't be surprised when recruiters court you. Such is the nature of our free enterprise—to recognize favorable buying and selling arenas and to capitalize on them. That's the way it should be.

But the undisciplined scramble generates so many conflicting demands on your attention that you may wonder, and your employer will question bitterly, why the technical societies that sponsor the meetings don't lay down some sanitary laws for the conduct of business. It boils down to this danger: if you are continually distracted from the basic business at hand, the presentation and discussion of engineering experience, authors will cease to consider the meeting as a platform from which to present their most important work. The quality of the papers will suffer from neglect and the meeting will lose its principal drawing card. Over-zealous selling and recruiting will kill the golden goose. A market place will be abandoned. The question of sanitary laws for technical meetings thus becomes vitally important to the vendor and the recruiter, as well as to you, the engineer who attends to learn something new. If you have fretted over this problem, you will be interested in a voluntary "code of conduct" that the National Flight Test Instrumentation Symposium has officially adopted for its get-together the first week of this month in San Diego. It requests that vendors not demonstrate equipment during the hours scheduled for technical sessions and that entertainment suites close during the same hours. It declares that recruitment is "not in proper taste"—in fact it's called "taboo"—during the entire symposium. That requirement seems over-righteous, but it's worth a try.

We consider this an extremely important experiment, because the principle that it will test is a key to the success and growth of the technical societies. We present the pros and cons for your evaluation, because of our concern. Care to comment?

V. E. Vaunah

at Imperial Oil Limited

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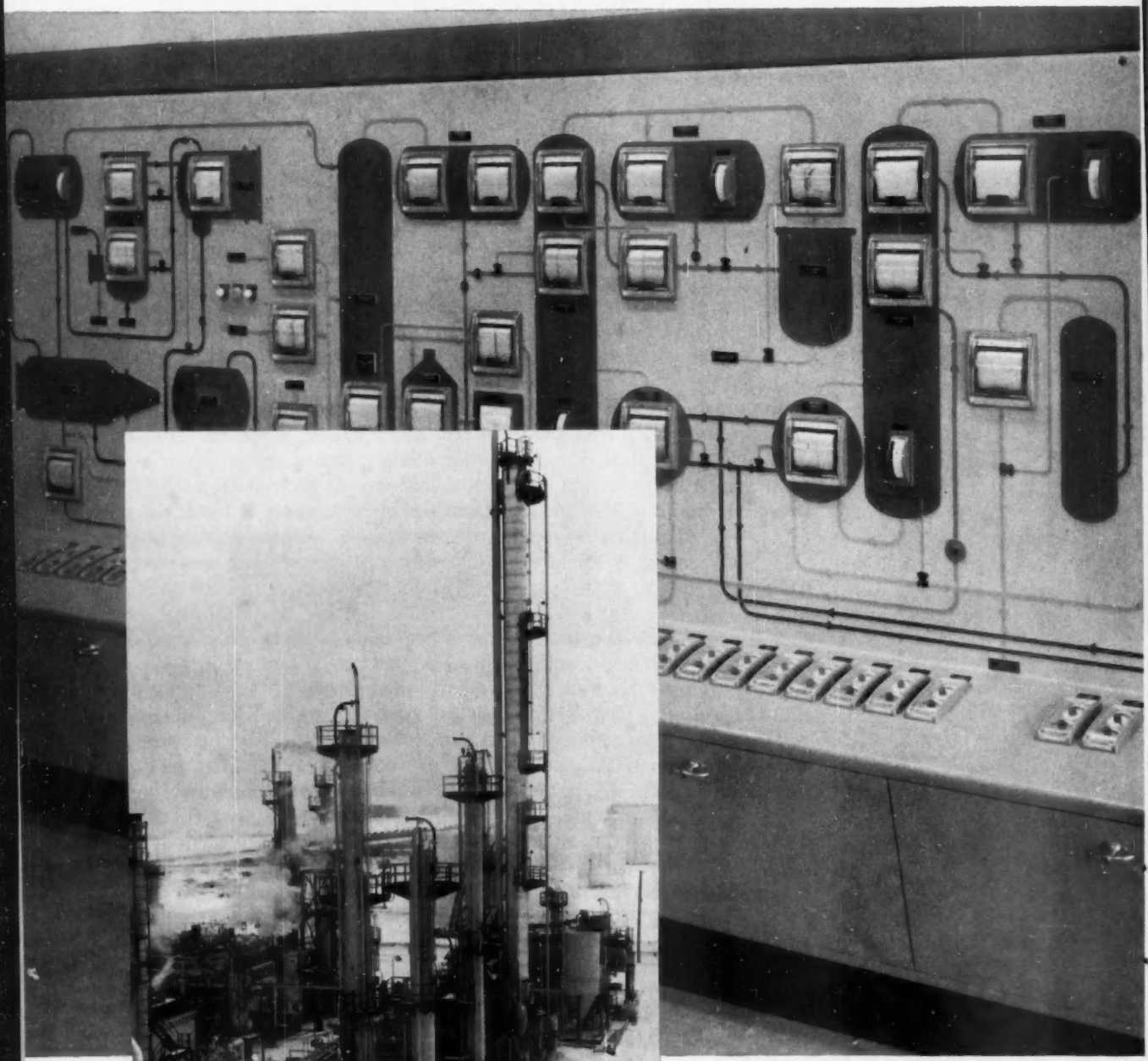
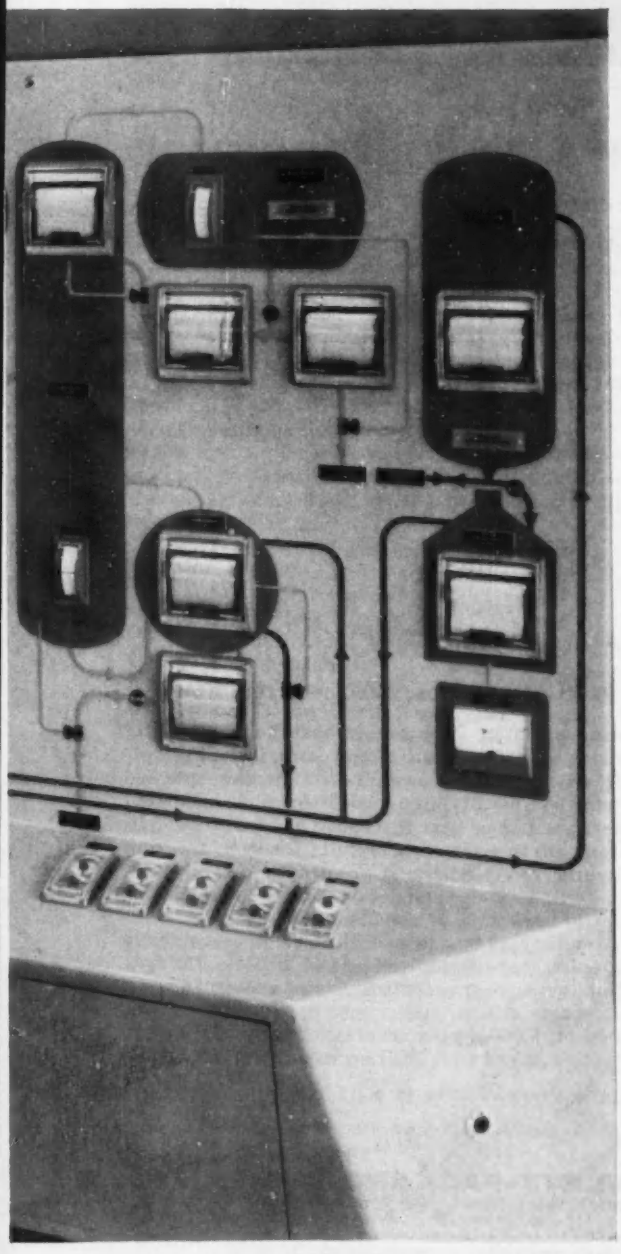


◀ New Hydrofluoric Acid Alkylation Unit at Imperial Oil Limited, Winnipeg, Manitoba. Unit was designed by the Universal Oil Products Company for Imperial Oil.

PHOTOGRAPHY BY FREDERIC ALKIER, WINNIPEG

maintenance electronic system... Electronic Consotrol instrumentation



▲ **FOXBORO ELECTRONIC CONSOTROL PANEL** at Imperial Oil includes 32 control loops. 3" x 6" Control Stations are so compact they are mounted on panel console, while recorders are mounted directly in the graphic diagram above.

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The Versatile Transistor NOR Circuit

Solid state switching techniques are poised for a large scale invasion of the industrial control field. Here the author discusses the design and operation of a single module—the transistor NOR—that is capable of performing all of the logic or low level switching functions in a control system, no matter how complex they may be. In addition, a hybrid equivalent of this module—the OR inverter—is introduced.

ALBERT N. DeSAUTELS
Maico Electronics, Inc.

In recent years the increasing complexity of industrial control systems has imposed major penalties on the reliability and size of these systems. In their efforts to lengthen service life and reduce physical volume, control engineers have concentrated on the switching operations within systems. Much of these operations involve only the low power levels associated with programming and interlocking, which are usually referred to as logical functions. The search for reliable and compact low level switching devices has led directly to solid state components, particularly transistors.

Although the transistor has a proven record in computer switching applications, it is only now that the time appears ripe for wide acceptance by industry. Two factors have helped establish the favorable atmosphere. Transistor design and manufacture have become comparatively stable, entitling it to recognition as a compatible industrial-quality component. And the development of a universal logic module—the NOR circuit—has made the transistor available in a form which can be employed directly in industrial control systems without demanding a great amount of original electronic design effort from the control engineer.

At this state of the art the basic logical functions of OR, AND, and NOT are widely known. The AND circuit is a configuration having an output and two or more inputs with the inputs arranged so that no output is obtained unless all inputs are activated. The simple diode circuit of Figure 1A illustrates AND logic. Under no-pulse conditions, both diodes are conducting and there is no output at C. A positive pulse at either A or B does not change the state of C. However, positive pulses at both A and B produce a positive reaction at C. Note that there is no inversion of signal in the AND circuit.

Figure 1B presents a diode OR circuit, which is a configuration producing an output when one or more inputs are applied. There is no interaction between signals, and as in the AND circuit, no inversion of signal. With no pulse on A or B, there is no output at C. A positive signal at either A or B causes conduction through R_s and yields a positive pulse at C.

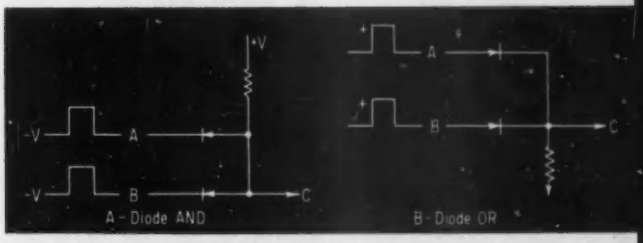

FIG. 1. Simple diode AND and OR circuits.

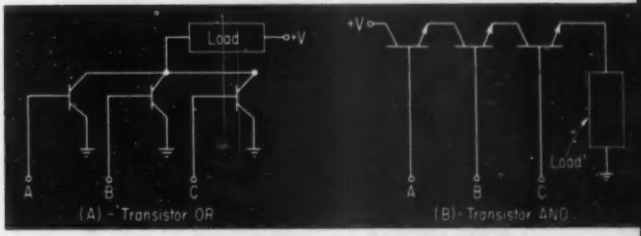

FIG. 2. Transistorized versions of basic logical functions.

The third logic element is the inverter or NOT circuit. The characteristic of the NOT circuit is that its output will be of opposite polarity to the input.

Transistor logic circuits

Although diodes make possible simple gate circuitry, they do not possess the gain and superior on-off characteristics of the transistor. For this reason the three-input transistor OR and AND gates of Figure 2 are of interest. These particular circuits employ NPN transistors; however, the principle applies equally well to PNP transistors with appropriate changes in polarity.

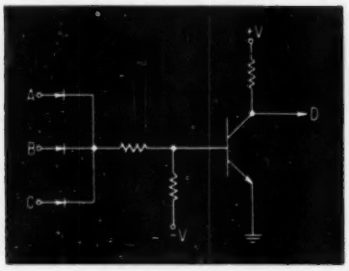

FIG. 3. Diode-transistor circuit for combination OR-NOT logic.

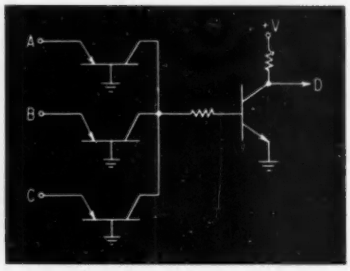

FIG. 4. Transistorized circuit for making OR-NOT decisions.

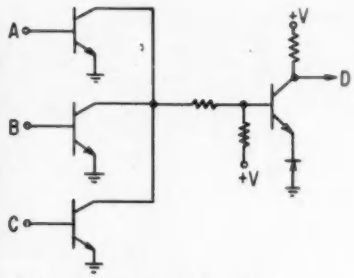

FIG. 5. Transistor NOT-OR-NOT logical chain.

In Figure 2A it can be seen that when current flows through the load, a positive signal appears at either *A*, *B*, or *C* as required for an OR logical unit. In Figure 2B, however, load current flows only when all three points *A*, *B*, and *C* become positive simultaneously. Equivalent logical functions can also be performed readily by electromagnetic relays. Although the make and break impedance characteristics of relays are superior to the on-off impedance characteristics of the transistor, the reliability and small size of the transistor are making it increasingly attractive in industrial control applications.

Diode and transistor logic circuits are often combined when the limitations of the application permit. Figure 3, for example, is a combination OR-NOT function in which diode logic supplies the OR condition, while the transistor provides the inversion. A sufficiently positive signal at *A*, *B*, or *C* will cause a decrease in voltage with respect to ground at *D*. If higher gain or discrimination is needed, the diode logic can be replaced by transistor logic, as shown in the OR-NOT circuit of Figure 4. Here a positive signal at *A*, *B*, or *C* will provide a negative-going signal at *D*. Figure 5 illustrates a combination NOT-OR-NOT circuit which provides a positive-going output when the input at *A*, *B*, or *C* is positive.

NOR circuit principles

The transistor NOR circuit is a single element that can perform all logical operations with a minimum of concern for input matching and output loading. NOR circuitry makes use of the switching facilities of a junction transistor in the common emitter connection. In addition to the junction transistor, the NOR logic circuit, or resistor-transistor logic as it is often called, includes a resistor *R* in series with the base lead and a current limiting resistor R_b in series with the voltage supply to the transistor collector. The emitter serves as the ground point.

The basic NOR circuit, Figure 6, can be defined as an amplifier inverter having a multiplicity of base resistors. Although PNP transistors are shown in the figure, NPN devices will serve just as well with voltage supplies of proper polarity. The building block consists of a resistor gate followed by an inverting transistor amplifier. The gate is an OR gate to ground signals and an AND gate to off-ground signals. The number of resistive legs on the input gate is referred to as the "fan-in" and the number of outputs which can be applied as collector loads is designated as "fan-out".

Assume initially that the transistor is cut off. The combination of V_{bb} and R_b supplies a bias to reduce transistor leakage current to a minimum. Thus, in the cutoff state, the negative voltage level at *E* is approximately equal to power supply voltage $-v_{cc}$. When a voltage pulse of sufficient amplitude and proper polarity is applied to the cutoff transistor at *A*, *B*, *C*, or *D*, current flows through *R* to the base, causing the transistor to saturate or turn fully on. Now there is an extremely low impedance between collector and emitter, and the voltage level at *E* approaches ground potential. Removal of the input pulse causes the transistor to cut off, and *E* returns to its previous level. Thus, the circuit of Figure 6 is properly regarded as a NOR circuit since an output exists only if neither *A* nor *B* nor *C* nor *D* is energized.

The NOR building block can be applied to perform the functions of AND, OR, and NOT. The latter is an inherent capability of the circuit and is provided simply by using only one of the input lines of Figure 6. A one-input NOR is a NOT or inversion circuit because if the input signal is 0, the output is 1. Conversely, the output is 0 when the input is 1. It is possible to consider a change in output from $-v_{cc}$ to ground potential as a positive-going output signal or 1. If this is done, the NOR element can be made to perform OR logic since a signal at *A* or *B* or *C* or *D* produces this positive-going output.

To convert the NOR element for AND functions, all of the input lines are given a negative bias. Thus the steady state output of the circuit is 1. A negative-going output signal is not produced until positive input

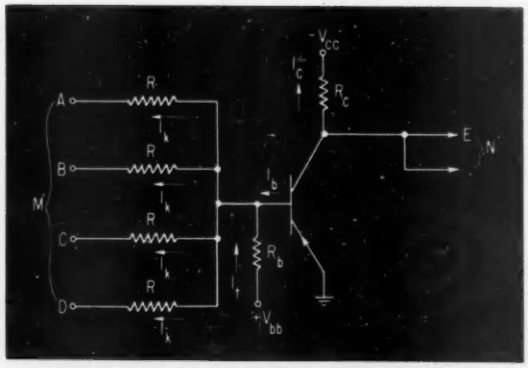

FIG. 6. Schematic diagram of resistance-transistor NOR circuit.

signal voltages are impressed on A and B and C and D. Thus, it is seen that all possible combinations of logic may be achieved with one basic building block. Although, in practice, refinements may be added to the basic circuit to improve temperature stabilization and operational speed, NOR combinations are compounded with a minimum of problems. Simplicity of the circuit makes it easy to provide individual tolerances that add up to the total allowable for the logic combination. In addition, the individual building block concept for assembling logical circuitry has the advantages of providing automatic isolation of failures and facilitating replacement of defective units.

NOR circuit design

The NOR circuit is extremely flexible. It can be subjected to various input and output loadings, a wide range of operating temperatures, and considerable variations in supply voltage. Nevertheless for practical application, it is well to know more definitely what can be expected from a circuit for certain operational conditions. With reference to Figure 6, the basic circuit parameters for the NOR circuit can be defined as follows:

I_k = minimum current through R for switching transistor on
I_b = minimum base current for switching transistor on
I_t = bias current needed to keep transistor off at maximum operating temperature
m = maximum allowable number of inputs
N = maximum allowable number of outputs
v_B = maximum base-to-emitter voltage with transistor full on
v_R = reverse base-to-emitter voltage to reduce I_c to I_{co}
I_c = maximum collector current
I_{co} = minimum collector current at maximum operating temperature
v_{cm} = maximum collector-to-emitter voltage with transistor on
v_{cn} = minimum collector-to-emitter voltage with transistor on
$-v_{cc}$ = collector supply voltage
$+v_{bb}$ = bias supply voltage
s = margin of safety multiplier to allow for future gain decrease (typical value is 2)

If transistor characteristics, dc operating points, and the number of inputs m are known, a useable NOR circuit can be designed using the following relationships:

$$N = I_c \left[\frac{R}{v_{cc}} - \frac{1}{sI_b + I_{co} + 0.25\,\frac{(m-1)}{R}} \right] \quad (1)$$

This equation indicates the maximum number of following NOR circuits or outputs that may be connected to the output of a given NOR circuit under the worst loading conditions. Maximum loading on the input occurs when a minimum input voltage is impressed on one input and all other inputs are grounded. For this case, the input current is given as

$$I_{in} = sI_b + \frac{v_{bb} - v_{be}}{R_b} - \frac{v_{be}(m-1)}{R} \quad (2)$$

I_b is determined by the minimum gain of the transistor for the chosen value of collector current I_c. v_{be} is a function of base current and is the voltage at the base with respect to the emitter.

$$R = \frac{v_{cc} - v_b - I_{co}R_c}{I_b} - NR_c \quad (3)$$

R_c is determined by the current limit desired for a given V_{cc}.

$$I_t = \frac{(v_{cm} - v_R)\,m}{R_b} + I_{co} \quad (4)$$

$$R_b = \frac{v_{bb} - v_R}{I_t} \quad (5)$$

$$I_b = I_k - I_t - \frac{v_b + v_R}{R_t} - (m-1)\,\frac{(v_{cn} - v_B)}{R} \quad (6)$$

Equation 4 can be solved for I_t, the current through bias resistor R_b when the transistor is not conducting. This relationship applies at the maximum expected junction temperature and with maximum input loading. I_t must be known for substitution in Equation 5 to find the value of R_b necessary to insure that the transistor will cut off at the maximum junction temperature. Equation 6 yields the value of I_b needed to establish an adequate base drive to saturate the transistor when input and output loading effects are maximum.

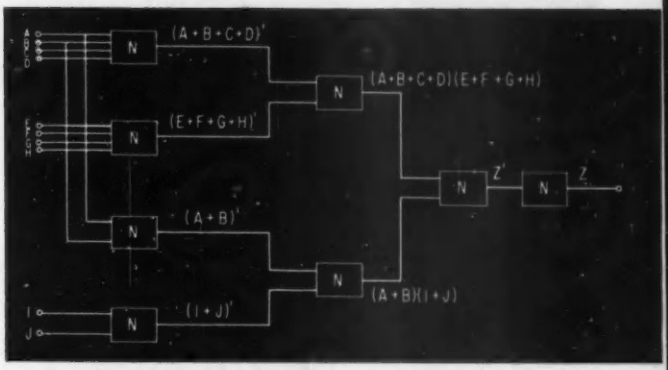

FIG. 7. Combination of NOR circuits to perform AND, OR, and inversion operations.

Capacitors may be added in parallel with each input resistor R to compensate for transistor hole storage effect and provide a "speed up" characteristic. The approximate RC relationship that establishes a practical value of capacitance is:

$$5\,RC \leq \frac{1}{\text{maximum repetition rate}}$$

For three or more inputs, it may be advisable to use speed-up capacitors. Simultaneous positive transients on two of the inputs will momentarily overpower the third, turning the transistor off and producing collector spikes.

Transistors to be used in NOR circuitry should be extensively tested to obtain individual units having optimum characteristics. Important parameters include the maximum value of I_{co} for a specific value of v_{cc} that is stable at the high temperature limit, the current gain associated with I_c just after saturation, and the collector saturation voltage (which should be less than 0.25 volts).

To illustrate the use of the NOR modules, assume

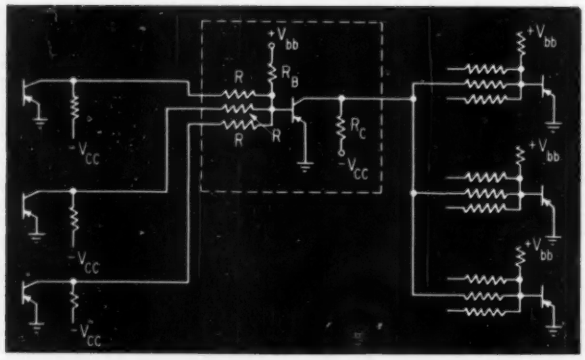

FIG. 8. Chain of NOR circuits shows output connections.

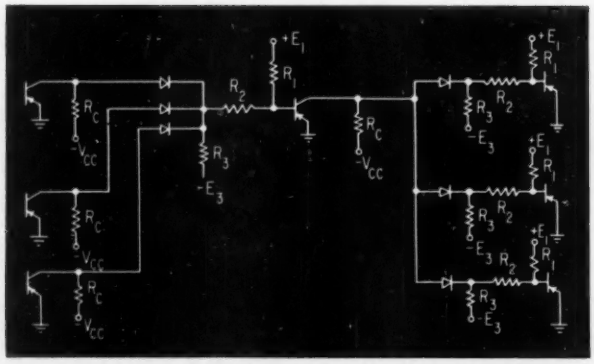

FIG. 9. Logical switching arrangement in which OR elements are substituted for NOR configuration.

that this Boolean expression is to be implemented:

$$(A+B+C+D)\,(E+F+G+H)+(A+B)\,(I+J)=Z$$

In Boolean notation the AND relationship is presented as a product and is known as logical multiplication. The OR function is stated as a sum and is known as logical addition. The diagram for performing this logic is shown in Figure 7. This arrangement uses eight NOR modules, each containing six resistors and one transistor for a total of 48 resistors and eight transistors. Diode gating for the same expression would require 18 diodes and seven resistors and possibly two or three transistors for amplification. The greatest single advantage of the NOR module is that there is but one building block for the designer to deal with and for his firm to manufacture or stock. A disadvantage is the need for two separate bias voltages in each module. NOR circuits are best used where there are many input and output variables.

NOR vs OR circuits

NOR circuits are likely to be used in a chain as shown in Figure 8. Here v_{bb} supplies through resistor R_b a cutoff bias which can be affected by variations in the saturation voltage of the driving stages. These variations in V_s are attenuated by an amount proportional to the ratio of R to $R + R_b$. Thus if the value of R is large compared to R_b, variations of V_s are attenuated sufficiently to have negligible effect on cutoff bias. A large value of R also makes the current supplied by each coupling resistor to the base of the on stage essentially independent of variations in the transistor input impedance. Another benefit of selecting a high resistance for R is that it tends to isolate the various inputs to a single stage. At the same time however, the high resistance limits the current available to charge the distributed capacity and to supply the base, and thus slows the switching speed. This is solved by using high Beta, high speed transistors.

Because transistor T_1 conducts when any of its inputs are negative, it will conduct if either T_2, T_3, or T_4 are not conducting. Should any one of the driving transistors be saturated, allowance must be made for the amount of current that is subtracted from the base drive by the conducting transistor. Large values of R decrease this feedback current but also decrease the available drive current.

A clamping diode connected between the collector of the transistor and an additional negative voltage supply (for the PNP version of the circuit) serves to limit the collector swing and prevent collector-to-base breakdown. If this expedient is adopted, R_c must be small enough to provide both current for the diode and sufficient drive for following circuits. The clamp does eliminate the effect of current variations in R which are caused by fluctuating I_{co}. Storage time, which limits the possible repetition rate, can be decreased by increasing v_{bb} to provide cleanup current. The effectiveness of this measure, however, is limited by a resulting decrease in turn-on time. Speedup capacitors can also be connected across R; although as previously stated, this action restricts the number of inputs which can be handled successfully.

From the earlier discussion of the adaptability of the NOR module to OR logic, it should be apparent that the combination of a conventional transistor OR with a conventional transistor NOT (inverter) can provide the functional equivalent of a NOR circuit. It is of interest to compare the pure NOR arrangement with the OR-NOT combination. For this purpose a typical OR-inverter chain is shown in Figure 9.

The chief advantage of this approach is the ability to provide a constant and well controlled drive to each stage. This drive is unaffected by either transistor parameters or the number of simultaneous inputs. The action of the module follows the most positive of the input voltages. If any input is sufficiently positive to cut off the transistors, variations of the other inputs are of no consequence. If all inputs are negative, the transistor conducts and the current in R_c determines the voltage on the cathodes of the input diodes. As long as all input voltages remain more negative than this value, variations in the input voltage do not affect the transistor. As in the NOR circuit, a speedup capacitor across R works well for providing cleanup current to decrease storage time. It can be noted from Figure 9 that the OR inverter module requires more components and would therefore cost more than the NOR module.

ACKNOWLEDGEMENT

The author wishes to thank Mr. Jay Wheeler, Maico Electronics, Inc., Digital Systems Dept., for contributions to portions of this article.

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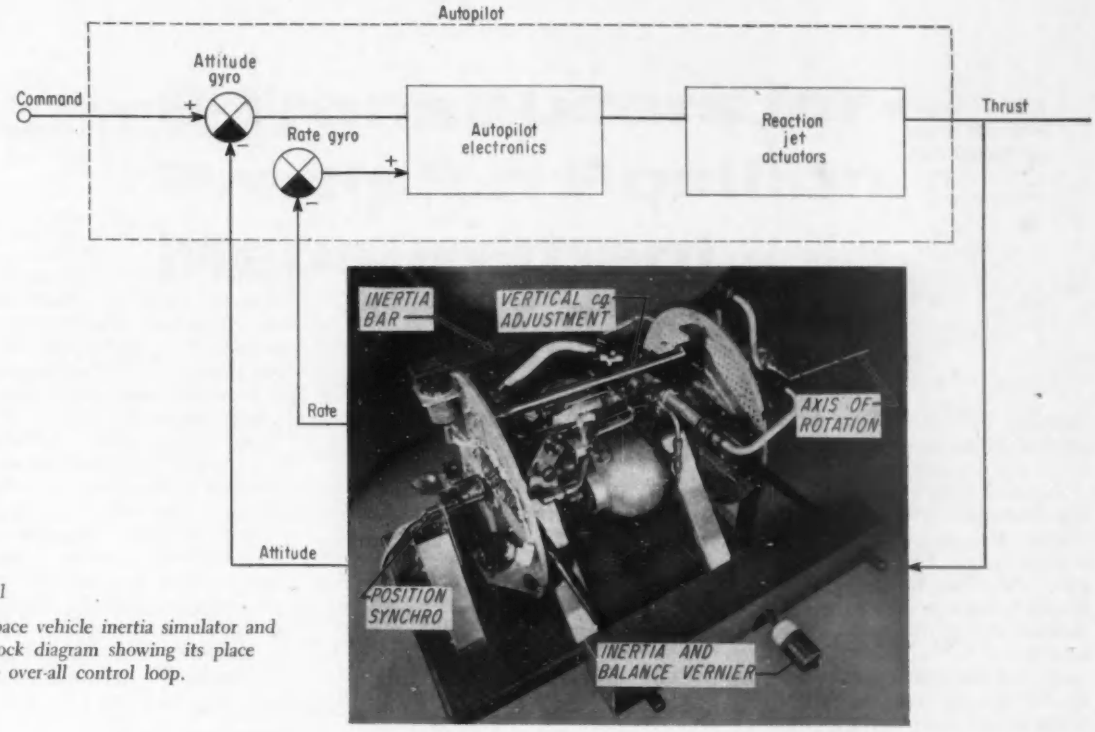


FIG. 1

A—Space vehicle inertia simulator and B—block diagram showing its place in the over-all control loop.

How to Compute Load Constants from Response Curve Data

B. B. BELLIT, Lockheed Aircraft Corp.

THE GIST: Analysis, test, and simulation of a control system which has a power actuator as an output device always involve specific knowledge of the load dynamics. Where direct measurement or computation of these constants becomes too complex, a graphical technique may provide the solution. Here the author describes such a technique as applied to a space vehicle inertia simulator. It requires one assumption . . . that the load behaves as a second order linear system.

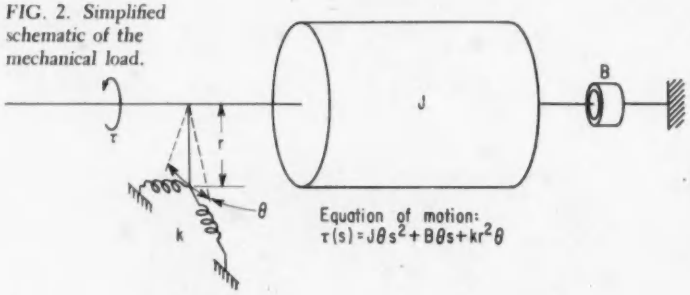
The rotating mechanical load shown in Figure 1A was designed and built to simulate the dynamic inertia of a space vehicle about one axis. Its closed-loop control system, Figure 1B, consists of a single autopilot channel which torques the vehicle through a set of reaction jets. The characteristic of the autopilot was readily measured —not so with the vehicle dynamics.

Certainly the load inertia and damping coefficient can be specified in advance to permit analysis or synthesis work to proceed, but at some point in the development of the system it becomes necessary to gain assurance that the actual mechanical constants of the load do indeed correspond to the values specified. In systems which drive irregular rotating loads like the simulator in Figure 1, computation of the actual load constant often poses a serious problem.

No direct approach

In Figure 1A for example, note that the simulator comprises a number of different density components, few of which are symmetrical about the axis of rotation. This layout precluded any attempt to compute total inertia by summing the inertias of the separate mass elements. The tests further required that total inertia of the load be adjustable between the limits of 12 to 35 slug-ft². Large steel bars, mounted on slide rods, provided this capability. Inertia could then be set by a repeated trial and error process. Direct measurement, however, still stood as a formidable barrier. Since the simulator characteristic was

FIG. 2. Simplified schematic of the mechanical load.



intended to approach that of a frictionless inertia, a measure of friction levels was also imperative.

Figure 2 represents a schematic of the mechanical system. Essentially it consists of a pure inertia J and a retarding viscous friction whose coefficient is B. Two springs, with a combined spring constant k, acting at a distance r from the axis of rotation, were added to facilitate the measurement. In effect the springs added restraint, thereby creating a conventional second order damped system.

Actually two alternate sets of springs were used: one with a compliance of 0.04 in. per lb and the other with a compliance of 1.0 in. per lb. This helped to determine whether or not a pseudo-spring force, produced by unbalance of the center of gravity in the vertical plane, was of any consequence. If results of tests using different sets of springs failed to show close correlation, a vertical adjustment of the center of gravity would provide the necessary correction. To insure linear performance of the springs, a slight preload was maintained in the zero or rest position of the system.

Graphical solution

Response to a step input was obtained by rotating the simulator through an angle of about 1½ deg, releasing it, and recording the time history of its angular position as the vibration decayed. A typical trace of angular position versus time is shown in Figure 3. A trace such as this was analyzed to yield ω_D, the damped natural frequency, and ζ, the damping ratio. These graphically determined values were then used to compute the inertia J and friction coefficient B of the load. From the equation of motion in Figure 3, the load transfer characteristic may be expressed as follows:

$$\frac{\theta}{\tau}(s) = \frac{1}{Js^2 + Bs + kr^2} \qquad (1)$$

This expression can be put in the more general form for a linear second order system, i.e.,

$$\frac{C}{R}(s) = \frac{1}{\frac{s^2}{\omega_n^2} + \frac{2\zeta}{\omega_n}s + 1} \qquad (2)$$

where ω_n, the undamped natural frequency, equals $\omega_D/\sqrt{1-\zeta^2}$. Solving for J and B in terms of ω_D and ζ yields the equations needed for computation:

$$J = \frac{kr^2(1-\zeta^2)}{\omega_D^2} \qquad (3)$$

and

$$B = \frac{2\zeta kr^2\sqrt{1-\zeta^2}}{\omega_D} \qquad (4)$$

Equations 5 and 6 below the response curve in Figure 3 show how the damped natural frequency is readily determined by the measured waveform period T_d and the damping ratio by measured peak amplitudes. The term x_m/x_o in Equation 6 is called the subsidence ratio. Actually x_o is the measured amplitude of any peak (positive or negative); x_m is the amplitude of the mth succeeding peak.

Figure 4 shows a logarithmic plot of Equation 6 using m as the parameter. Once the subsidence ratio has been computed, the damping ratio can be read directly from the appropriate m-curve. Such a plot can be quite useful, particularly in work involving a trial and error test.

Application limits

While the graphical method described above has proved successful in the case of the inertia simulator, it cannot be applied indiscriminately. The entire procedure is predicated on the existence of, or creation of, a second order linear system. To determine whether or not a particular system lends itself to this technique, it will be necessary to first compare its response to that of the second order system. If its period of oscillation is constant and the subsidence ratios correspond to those of the perfect system, then the technique can be used.

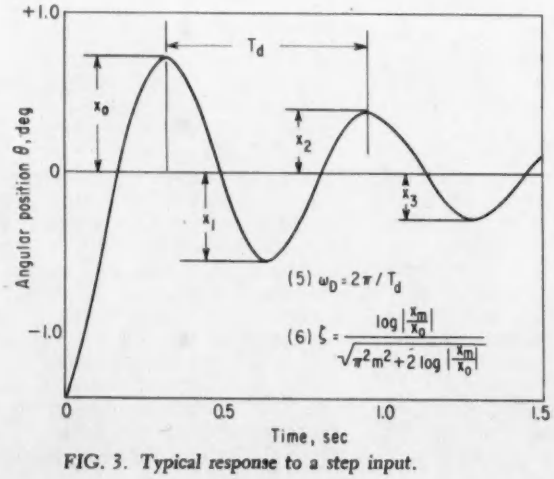


FIG. 3. Typical response to a step input.

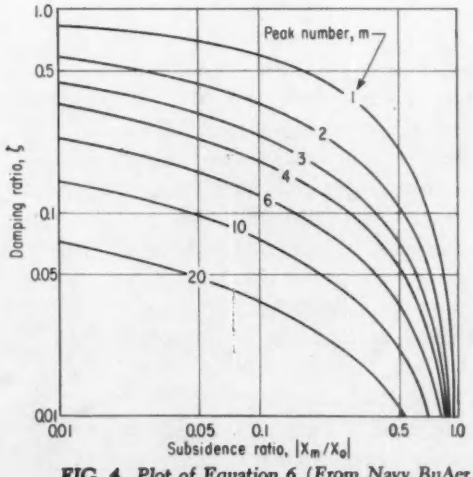


FIG. 4. Plot of Equation 6 (From Navy BuAer Report AE-61-4, Volume I, pp A-21).

6 Transducers for Precision Position Measurement

THE GIST: The increased sophistication of numerical control systems users has cleared up the early misunderstanding that a precise control alone could make up for inherent faults of the machine. Now fully aware of their responsibilities in gaining accuracy objectives, machine builders are steadily improving the art of mechanical design. But they are making things harder for the control engineer. With the machine builder now really able to use high electrical accuracies, control engineers may have to upgrade their systems. Top attention must be given to the position measuring transducer, since it sets the accuracy limits of the feedback loop. Author Morin describes six high precision transducers with measurement capabilities up to one part in a quarter million.

1. PIN-AND-PAWL MECHANISM

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The electromechanical arrangement shown in Figure 1 has been applied successfully to a rotary positioning table with a resolution of better than 5 sec of arc, or one part in 260,000. It makes use of a series of pins or bench marks separated by precise 2-deg increments. An auxiliary slide-mounted contact actuator permits interpolation between any two adjacent bench marks. The concept is applicable also to linear point-to-point positioning systems of any length, but not to continuous path control.

At the start of a positioning sequence, the pawl is disengaged from the pins and the table rotated to the closest 2-deg point by means of a rapid traverse motor and coarse instrumentation. The table is allowed to overdrive so that the pawl can drop in behind the nearest pin. The rapid traverse motor is then declutched, and a creep motor, which always turns the table clockwise, is energized. Simultaneously, the pawl slide is driven through a slip-clutch so that the pawl always maintains positive contact with the selected pin. As the table rotates slowly, the pawl slide moves until the contact actuator is tripped by a dog on the pawl slide. When the contacts operate, the table drive is declutched and the table, clamped.

Note that the pawl strikes an adjustment screw located beside the pin. The pawl has an angular face contacting the pin so that moving the screw in or out changes the position of the table at which

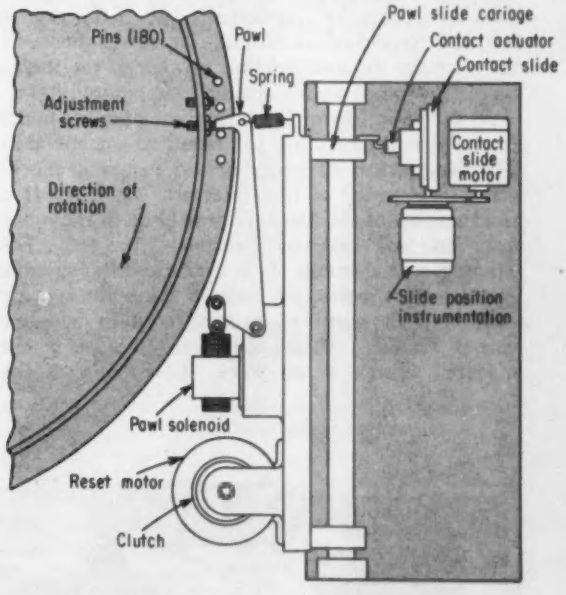


FIG. 1. Warner & Swasey electromechanical position transducer based on pin-and-pawl mechanism.

the pawl slide trips the contact actuator. Adjusting these screws precisely locates switching points.

The contact actuator is mounted on a slide so that it can be moved forward or backward relative to the pawl dog. The slide is instrumented and powered so that it can be preset to the desired fraction of the 2-deg interval. Thus the contact actuator slide provides the means of interpolation between bench marks. Because of the limited range of the slide, its accuracy requirements are much less than the overall accuracy of the system. To permit interpolation to the nearest 0.001 deg (3 sec of arc), for example, the slide position must be set to one part in 2,000, which is well within the capability of precision screws. The rough instrumentation for locating any given pin needs an accuracy of about one part in 300 or 400, which can be provided by synchros, potentiometers, or switches.

2. MAGNETIC BENCH-MARK SYSTEM

In a magnetic analogy of the pin-and-pawl arrangement, the pins are replaced with magnetic blocks, and the pawl is replaced with an *E*-shaped electromagnetic reading head. The Pratt and Whitney Co., Inc. manufactures positioning control systems of this type. The magnetic transducer has a major advantage over the pin-and-pawl device because the reading head does not touch the magnetic block, so that the transducer never needs recalibration to compensate for wear.

This magnetic transducer is more complex than the mechanical device. Even at maximum error the signal from the reading head is at a low power level, and as the position error becomes smaller, the output voltage drops proportionately. To maintain good accuracy, a reasonable amount of voltage gain is required. In addition, sufficient power gain must be furnished to operate either a continuous or contactor servo. Like the mechanical device, this transducer uses blocks of position data for both coarse positioning and for the vernier. However, because the vernier is a two-speed servo, it requires more data than its mechanical counterpart. As in the case of the electromechanical system, there is a necessity for resetting the interpolation vernier, so the instrumentation is not readily adaptable to contouring.

As shown in Figure 2, the machine member under control has a measuring bar mounted on one side. The bar consists of a number of magnetic blocks accurately located at 1-in. intervals. Attached to a fixed portion of the machine head close to the measuring bar is a balanced *E*-magnet structure. The winding on the center leg is excited with a suitable voltage; the windings on each of the outer legs are connected in series opposition to form a single output winding. When the reading head is at the magnetic center of the block, the voltages in the two legs are balanced and the output is zero. At any other position the output voltage has a magnitude and phase proportional to the distance and direction from the magnetic center of the blocks. As the table is moved, the output of the sensing head decreases to zero once for each inch of movement. For maximum precision the magnetic center lines are accurately located by stoning the sides of each block. In addition, the cumulative error in the string of bench marks can be made to approach zero by proper calibration of each point.

Interpolation between bench marks is accomplished by presetting the reading head to the fraction of an inch desired. This positioning is done by means of a motor driving a precision screw which carries separate feedback instrumentation. The position of the table that produces a null signal from the sensing head shifts as the head is moved with the precision screw.

When the machine member is to be positioned, it is driven first to the correct 1-in. point by means of a motor and coarse instrumentation on the table. The member then moves at greatly reduced speed until the output from the reading head is zero. The member is always positioned in the same direction to obtain the best repeat accuracy.

The accuracy required in the calibration of the bench marks is at least as high as the accuracy objective for the overall system. In the case of the Pratt and Whitney devices, the bench marks are located to better than plus or minus 0.0001 in. Similarly the reading head accuracy is maintained at plus or minus 0.0001 in. over a distance of 1 in. (one part in 10,000). This requires a two-speed position control on the interpolation vernier. As in the electromechanical device, systematic errors are calibrated out, but random errors are unaffected.

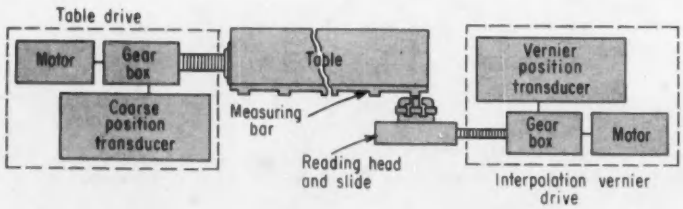


FIG. 2.
Position transducer using magnetic bench marks.

3. RESOLVER-TYPE TRANSDUCERS

Resolvers are in common use as feedback transducers. In this device a magnetic field established in the stator produces a voltage in the rotor output winding whose phase or amplitude depends on the mechanical angle between rotor winding and stator windings. At the present state of the art, one revolution of a resolver cannot be divided into more than about 1,000 parts. If higher accuracy is needed, the resolver must be geared so that it makes many revolutions for each revolution of the driven member. Even in such design, gearing inaccuracies, not resolver errors, limit the system accuracy to within about 10 or 20 sec of arc.

To avoid gearing errors it would be advantageous to have a resolver with a great number of poles so that it can be directly coupled to the driven member. This is actually possible in the Farrand Inductosyn in which the stator and rotor are wires printed on a pair of stable glass discs, rather than wires imbedded in an iron structure. For use in binary systems, it has been made with 128 poles in which the rotor voltage completes 64 cycles per revolution. Decimal systems typically use 200 pole units delivering one complete rotor voltage cycle every 3.6 deg.

In practice the Inductosyn is coupled directly to the rotating member. A conventional resolver also coupled to the driven member locates the proper 3.6-deg interval of the Inductosyn. When the correct interval is reached, the Inductosyn stator is excited with a pair of voltages representing the sine and cosine functions of the angle between the rotor and stator at the desired table position. At this position the rotor voltage is zero. The driven member is then rotated until a null detector indicates that rotor voltage has decreased to zero. The output voltage for a 10-sec error from null is about 5 to 10 microvolts, which has to be amplified to be useful.

The Inductosyn requires no calibration because the fixed position of the printed wiring determines accuracy. Errors are held to a few seconds of arc. The entire rotor couples to the entire stator so that local irregularities in the printed pattern are averaged out. In addition, both systematic and random eccentricity and run-out do not contribute errors. Accuracy really depends more on the electronics driving the Inductosyn than on the device itself. The two-phase 10-kc input signals, which are derived from a digital to analog converter fed from the tape, must have low distortion and must also have extremely good amplitude regulation. Also, the magnitude of the rotor voltage at any given angle is a function of the stator-to-rotor air gap; hence this distance must be maintained constant. In effect the coarse instrumentation divides a circle into 100 parts, and the Inductosyn subdivides each of these into 1,000 parts to provide a resolution of one part in 100,000 or approximately 10 to 12 sec of arc.

The linear version of the Inductosyn similarly comprises precisely spaced conductors printed on glass plates. One plate, called the slider, is fixed to the bed of the machine and acts as the stator. The second plate, or scale, attached to the moving member serves as the rotor. The slider is arranged in two circuits, one-quarter cycle out of phase with each other, which form a two-phase stator with one cycle extending over 0.1 in. of movement. The linear Industosyn has been used to discriminate increments of less than 0.00002 in. over a total length of 20 in.

4. ELECTROSTATIC TRANSDUCERS

Figure 3 is a schematic drawing of an electrostatic transducer designed by the Telecomputing Corp. to measure the angular position of a precision theodolite. The transducer consists of a pair of stable circular glass plates. One of these is attached to the movable member whose position is to be measured, and the other is attached to a fixed member. The two discs are mounted concentrically, with their faces separated by a small air gap. All electrical connections are made to the fixed or driver disc.

Photoetched metallic patterns are bonded to the surfaces of each disc. The complicated pattern on the driver disc, Figure 4, consists of concentric rings 1, 2, and 3, which form the output circuit, and bands *A*, *B*, *C*, and *D*, which form the input circuit. Bands *A* and *B* and bands *C* and *D* are pairs of conjugate sinusoids which are separated by 90 deg. Two ac signals 90 deg apart in time excite the driver bands.

The pattern on the coupler consists of two alternate rows of bars and spaces, Figure 4B. The bars

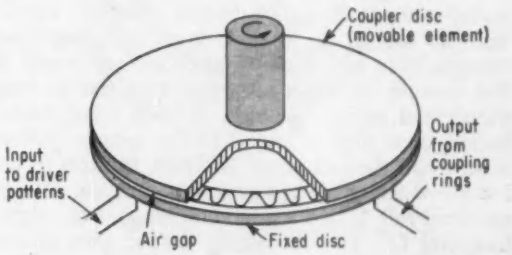
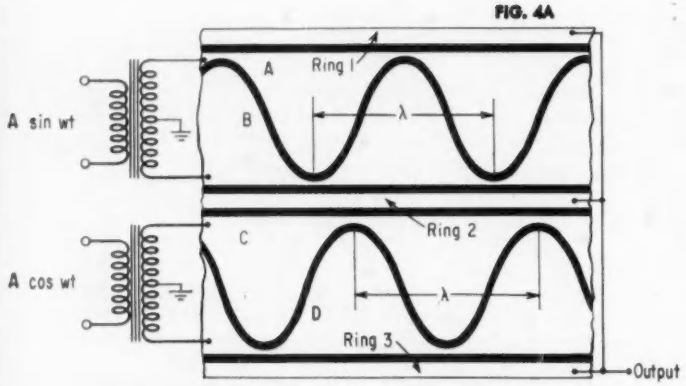


FIG. 3. Schematic assembly of electrostatic disc transducer.

are shown as rectangular elements for simplicity. Actually they are sectors of circles concentric with the axis of rotation. The widths of the bars and spaces are the same, being equal to one-half the wavelength of the driver sinusoids.

Figure 5 is a composite of the coupler and driver patterns. The bars in the coupler pattern present



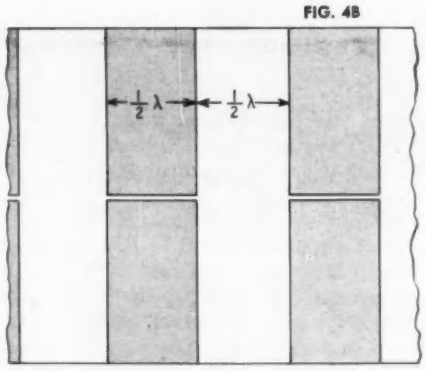


FIG. 4. Patterns deposited on discs for electrostatic transducer.
A—Drive pattern.
B—Coupler pattern.

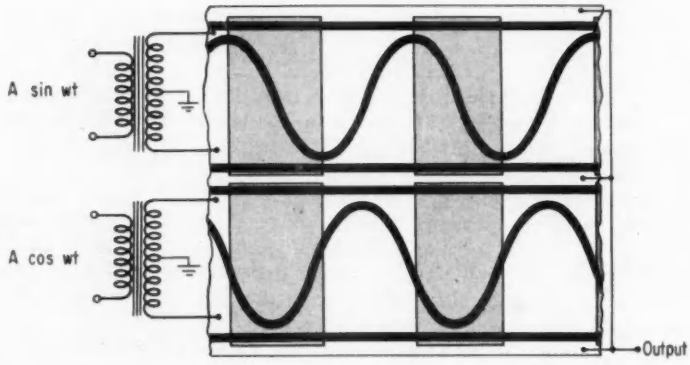


FIG. 5.
Composite of driver and coupler patterns.

varying amounts of capacitance to the driver pattern, depending on their relative positions. Therefore, the amount of current coupled (from the driver bands through the coupler bars to the output ring) is also a function of their relative position. In this case the bars in the upper row are coupling equal voltages from each member of driver pair *A* and *B*. But because the driving voltages are equal in magnitude and opposite in sign, the net signal contribution from rings *A* and *B* to the coupler pattern is zero. At the same time, however, the bars in the lower row are coupling a maximum amount of voltage from ring *D* and a minimum amount of voltage from ring *C*. The net voltage derived from output rings 1, 2, and 3 is the vector sum of the four coupler voltages. This output voltage is constant in amplitude but has a phase angle, relative to any one of the input voltages, that varies from 0 to 360 deg as the coupler bars move across each sinusoid.

In addition to the patterns just described, another set of concentric patterns is deposited on the discs to measure their rough position. The second set is similar to the first, but has a period equivalent to 180 deg of mechanical rotation. The device has to rotate only one-half revolution; hence 180-deg symmetry is acceptable. This could be changed easily to provide for continuous rotation if necessary. Since the coarse and fine patterns are closely spaced, there is possibility of cross-talk which can cause measurement errors. To avoid this the patterns are excited at two frequencies and the outputs passed through tuned filters to remove unwanted components.

The output of a unit constructed with 200 elements in the fine pattern resembles that of a 400-pole resolver. The phase of the output voltage advances 360 electrical deg for each 1.8 deg of mechanical rotation, and this signal can be further subdivided into 1,000 parts. Hence the position of the rotating member can be measured to one part in 200,000 or about 6 sec of arc. To achieve this resolution the pattern accuracy must be held to a few seconds of arc. Because the net output is an average of all the elements, local irregularities in either pattern are canceled out. Likewise, systematic and random errors are automatically compensated for.

As a system component, this transducer has many of the same requirements as the Farrand device. The stator must be excited with a set of high audio frequency (0.5 to 30 kc) excitation voltages that are low in harmonic distortion, matched in amplitude,

and exactly 90 deg apart in phase. The output voltage level is quite low (a few millivolts), as is the power level. This transducer has two major advantages, however. It requires the generation of only one command voltage, with consequent reduction in the amount of logical circuitry. And this command signal consists of phase-shifted data which can be generated simply and accurately by means of electronic counting circuits. In addition, counting techniques can be used to measure the error between the command signal and the transducer output, although phase sensitive discriminators are employed in the Telecomputing Corp. system.

The problems involved in generating a 20-kc phase-shifted signal accurate to plus or minus 0.1 percent, either by switching tapped transformers or by electronic phase-shift decoders, limit the speed at which command data can be obtained. Thus it appears that this approach will be confined to positioning rather than continuous path systems.

5. CODED-DISC TRANSDUCER

One type of optical device is particularly useful in digital control systems because its output is a binary number representing the angular position from a fixed zero reference point. This transducer uses binary-coded discs, Figure 6, of the type manufactured by The Baldwin Piano Co. and W. and L. E. Gurley. The discs of dimensionally stable glass carry a pattern of clear and dark areas. As shown in Figure 7, a lamp illuminates the disc and transmits its pattern through a slit to a bank of photocells aligned along a radius. There is one cell for each zone or band on the disc. The output from the photocells constitutes a binary number uniquely associated with a particular mechanical angle. For an N zone disc, 2^N angular positions can be identified.

At the present time, at least one supplier of these transducers offers an 18-zone encoder having 263,144 quanta in the finest zone. This unit theoretically permits measurement to slightly better than 5 sec of arc. A disc of this resolution must be illuminated with a flash lamp because a steady intense light source would cause irregular heating effects that would lead to large errors. No coarse instrumentation is required since all the necessary position information is included in the 18-bit binary number.

The binary-coded disc transducer is commonly used as the feedback element in control systems of moderate accuracy (one part in 60,000 or less). The reason for this popularity is the convenient numerical form of the transducer output and the command input. The error detector employed here is some type of device which produces a voltage proportional to the difference between the command number and the feedback number. Generally the error detector requires only a limited proportional range. Its output should be linear over the seven or eight least significant bits but may be saturated or constant for errors greater than this.

Because command numbers can be generated by electronic counting techniques at a fairly high rate, this transducer is applicable to both contouring and positioning systems. In contouring systems, feed rates are limited by the sampling rate of the lamp, which is generally less than 100 flashes per sec. The effect of sampling is to introduce a time delay in

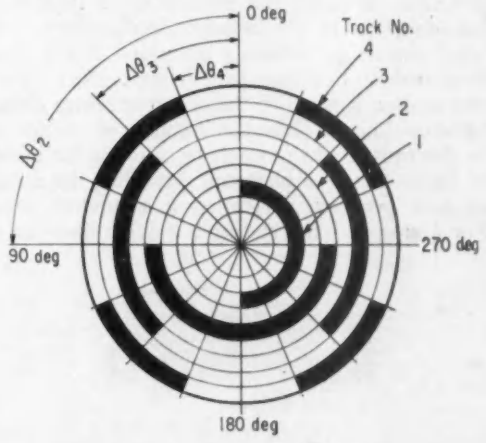


FIG. 6.
Binary coded disc for optical transducer.

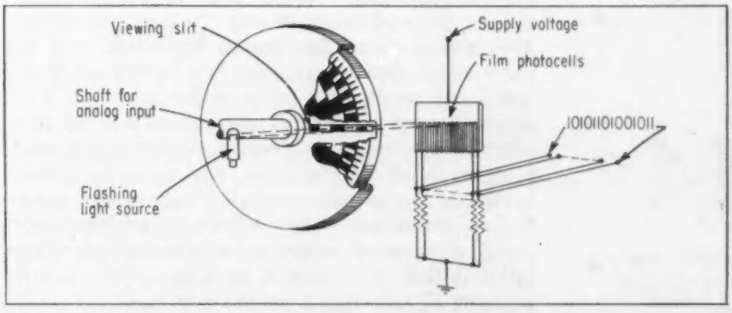


FIG. 7. Schematic of reading arrangement for optical transducer.

the feedback loop, thus making the response of the system somewhat slow for high feed rates.

Linear binary strips have been made with a pattern accuracy of plus or minus 0.0001 in. Since the pattern is sensed along a narrow line, it is extremely difficult to join lengths of strips to form longer scales. Maximum length at present is about 3 ft.

In this type of transducer the output number depends on the illumination of zones lined up along a single radius. Any runout, bearing noise, or eccentricity will cause shifting of the zones and, hence, incorrect readings. In addition, the amount of light incident on the photocell sensing the outer zone is very small, making reliable readings difficult. These are the principal reasons why coded discs are not widely accepted for high accuracy applications.

6. DIFFRACTION GRATINGS

A second type of optical transducer uses coarse diffraction gratings that provide a shifting light intensity pattern as the gratings move relative to each other. Figure 8 shows one such grating as it would be mounted on the side of a machine. It has an accurately known number of lines per inch that are ruled at right angles to the direction of motion. A similar grating is superimposed over the first grating and is slightly tilted. When the gratings are illuminated, the angular intersections of lines on the two gratings interfere with the light passing through and create a pattern of moire fringes. The pattern's light intensity distribution is roughly sinusoidal.

When one grating is moved with respect to the other at right angles to the line structure, the fringe pattern shifts in the direction of the lines. The direction in which the pattern shifts depends on the direction of the relative displacement. If a small area of the pattern is examined, it will change from dark to light and back to dark when the relative motion is equal to the center-to-center distance between lines. Thus the amount of motion can be determined very precisely by counting the number of bands passing a photocell, providing the number of lines per inch of grating is accurately known. For example, if the grating has 1,000 lines per in., motion of 0.1 in. will cause 100 interference bands to pass the inspection point.

If direction of motion is to be determined, there are two points of inspection, separated by an odd number of quarter wavelengths of the fringe pattern. Their outputs form a two-phase electrical signal containing information on both the amount and direction of motion. In addition, the occurrence rate of the fringe pattern is a measure of the rate of motion.

The accuracy of the transducer is a function of the number of lines per inch of the gratings. Systems using this device produce an output pulse when the area examined is at maximum light intensity and again when the intensity is a minimum. Therefore, a grating with only 500 lines per in. can be used to measure to 0.001 in. Since gratings with 5,000 lines per inch are readily available, a measurement accuracy of 0.0001 in. can be realized.

This measuring system is entirely free from friction and wear. Because the position information is the integrated result of a large number of line intersections, lengths of grating can be placed end-to-end with small gaps to simulate a single long grating. The loss of a few lines merely lowers contrast slightly. Dust and scratches and local irregularities in the ruling have little effect on the accuracy.

Diffraction-grating instrumentation has been used very successfully in a two-axis numerically controlled contouring system. The feedback signal is a pulse train whose rate and number determine the speed and distance of motion. The command signal is of the same form and is easily generated by electronic digital data processing techniques. This transducer can be used for end-point positioning, in which case the command data is used to preset a counter, which is then counted down to zero by feedback pulses. The transducer as described is applicable only to incremental systems; i.e., systems having no fixed initial zero or reference point on the machine. The device cannot distinguish one position from any other position but only measures the distance moved from an initial starting point, which can be placed anywhere. In programming, all dimensions are specified as incremental motions from an arbitrary zero point. One disadvantage of incremental instrumentation is that if an error is made in moving to any position, all subsequent positions are in error.

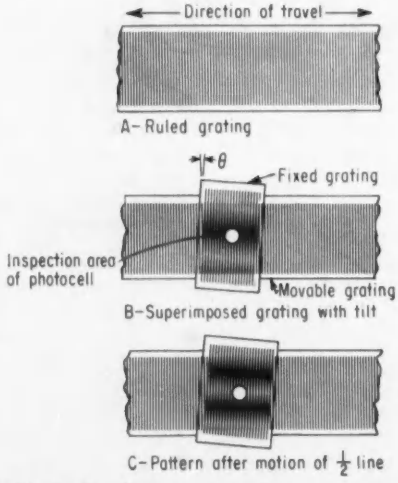


FIG. 8. Interference patterns in a diffraction-grating type of transducer.

STREAM ANALYZER DYNAMICS
Part I—
Testing Techniques and Apparatus

THE GIST: Large enough dynamic lags in stream analyzers can cause detectable measurement errors and system instability. This first of two articles shows how dynamic errors can result from stream temperature and composition changes and from instrument servosystem response. The authors also set up the techniques and apparatus for making pulse-like disturbances in refractive index, composition, and temperature.

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J. O. HOUGEN, Monsanto Chemical Co.
G. E. DREIFKE, St. Louis University

The Meecomatic Model 2 continuous differential refractometer (Ref. 1) was selected as the instrument for studying analyzer dynamics. Its optical circuit is shown in Figure 1. The refractometer monitors process stream composition by measuring the difference between the desired refractive index (reference cell, Figure 1) and the sample stream (sample cell) being examined. The resulting signal can be fed back to a controller to exert corrective action on the process.

Of particular interest here is the dynamic response of the detector cell. This cell is of the Anderson type, comprised of sample and reference sections. The low-sensitivity cell used during the dynamics study has a reference cell window at an angle of 15 deg from a normal to the light beam. Note that the temperature reached by the reference liquid is the result of direct heat transfer from the flowing sample stream. It is this method of adjusting reference liquid temperature that gives rise to a thermal lag and a resulting error in refractive index measurement.

When sample and reference liquids have the same refractive index, light will pass through the cell with no net refraction. However when the sample's refractive index differs from that of the reference liquid, the light will be refracted at an angle which, if small, is directly proportional to the difference in refractive indices of the sample and reference liquids.

A liquid's refractive index varies with concentration, so that stream composition can be correlated—as is done by the refractometer—to refractive index. However, a liquid's refractive index is also sensitive to temperature changes. So long as the liquids in the sample and reference cells are at the same temperature, there is no net change in refractive index. But a cell temperature difference is interpreted by the refractometer as a composition error. This is a

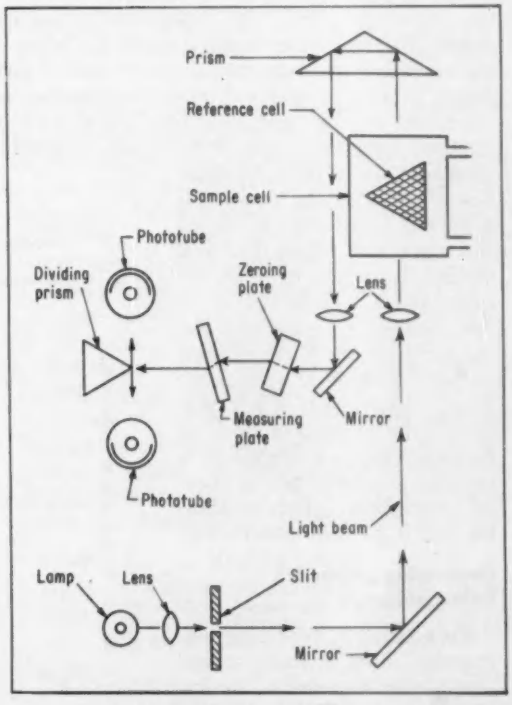


FIG. 1. Meecomatic differential refractometer used to study analyzer dynamics.

dynamic error, diminishing with time as the sample and reference cell temperatures equalize.

Composition changes, particularly abrupt ones, in the sample cell also introduce a dynamic lag and error in instrument output. Some finite time is required to fill the sample cell with liquid of new composition, during which time indicated concentration differs from the true value. Furthermore, as was found during the investigation, mixing striations and insufficiently mixed globules diffused and scattered the light beam, causing the refractometer to drive off scale until the striations had disappeared. Thus a dead time was added to the dynamic lag caused by composition change.

A third source of dynamic lag besides the two arising in the detector cell is that due to the mechanical inertia of the basic instrument servo. While the cell dynamics due to changes of temperature and composition were of primary importance in the investigation, it was first necessary to determine the instrument response, since during test runs the instrument response was included in the dynamic response of the detector cell. Thus to obtain the actual cell response, it was necessary to subtract out, so to speak, the instrument dynamics.

Pulse changes for dynamics tests

To carry out experimental tests on the detector cell's response to changes in composition and temperature requires techniques and apparatus for introducing pulse changes in composition, temperature, and refractive index. All experimental data were obtained by the pulse response method. Input disturbances and resulting output signals were recorded simultaneously. Input and output magnitudes were correlated on the same time base (dead time was removed from the output record) and prepared for processing on an IBM 702 computer. The computer performed a Fourier transform analysis of the input and output data and divided the output result by the input result. Final results of the computer program were the transfer function values relating output to input at various selected frequencies, which permitted the plotting of Bode or frequency response diagrams. A detailed discussion of the Fourier transform approximation method is given in Reference 2.

Generating refractive index pulses

To accurately determine cell response, it was necessary to first observe the response of the instrument to a disturbance equivalent to a refractive index pulse. This was done by removing the detector cell from the refractometer and displacing the zero-balance plate by a known angle. With the cell removed and the light beam unobstructed, the zero-balance plate was adjusted to give zero output signal. The zero-plate position was noted and the plate then moved to give full output. Again the position of the zero plate was noted. Since the instrument had responded through its full span for the balance plate in use, the observed shift in the zero plate was equivalent optically to a change in refractive index equal to the span of the balance plate used.

The zero plate was readjusted to give zero output, and then the light beam was obstructed. The zero plate was shifted through a known portion of the range, usually about 75 percent, required to give full output. This was equivalent to placing a solution of known refractive index higher than the reference into the detector cell. The light beam obstruction was then removed and the instrument allowed to respond for a known time before the obstruction was reinserted. This effectively excited the refractometer with a square pulse of known amplitude and width. Various pulse lengths were observed and the results recorded.

Experimental frequency response data for the basic instrument, obtained by the Fourier transform method, is shown in Figure 2. Standard profiles (Ref. 2) fitted to these data indicated that the refractometer is a second-order system with a damping ratio of approximately 0.8, an undamped natural frequency ω_n of approximately 0.21 rad/sec, and an instrument gain K_i of 1.83. These data were observed at the value of amplifier gain which gave the best response time on the instrument. Increasing gain caused the system to oscillate for a longer period due to a reduced damping ratio. Decreasing

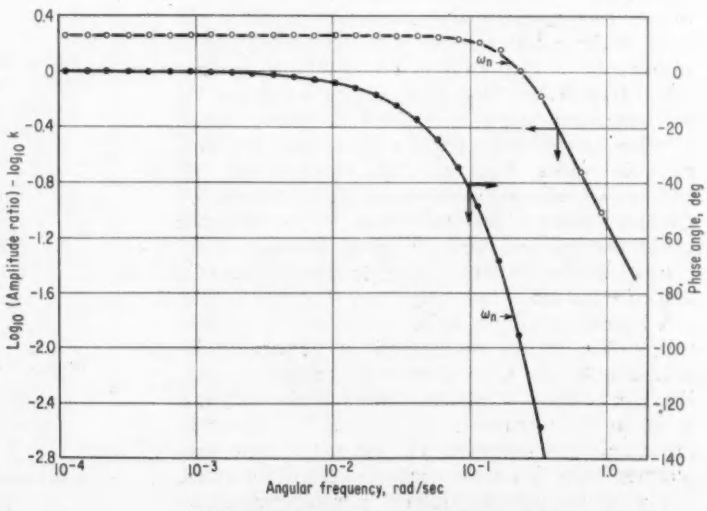


FIG. 2. Frequency response of basic instrument servo obtained by Fourier analysis of transient response to equivalent of a pulse change of refractive index.

APPARATUS FOR TESTING ANALYZER RESPONSE

• TO PULSE CHANGES OF STREAM COMPOSITION

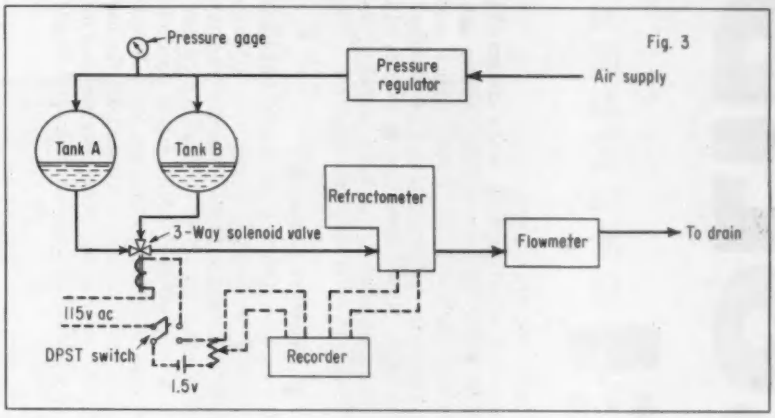
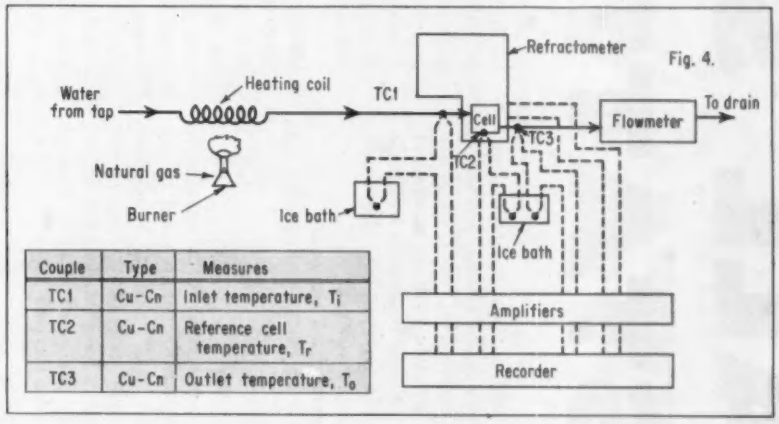


Fig. 3

• TO PULSE CHANGES OF STREAM TEMPERATURE



Couple	Type	Measures
TC1	Cu-Cn	Inlet temperature, T_i
TC2	Cu-Cn	Reference cell temperature, T_r
TC3	Cu-Cn	Outlet temperature, T_o

Fig. 4.

gain resulted in a slow, sluggish response from the increased damping ratio. These data were obtained using a 4-sec pulse width. Other tests with longer pulses were run. Their results agree; but as the pulse lengths increased, the reliability did not extend to higher frequencies. Analysis of the refractometer servo confirmed the experimental results.

Generating composition pulses

The test apparatus for generating composition pulses is shown in Figure 3. Distilled water, at room temperature, from Tank A was passed through a three-way solenoid valve to the instrument until the instrument output was stable. The solenoid valve was then switched to admit from Tank B a solution of ethylene glycol of known refractive index. After a known time (the pulse duration) the valve was switched back to the distilled water line. Recordings were made to the same time base of the instrument response and of the solenoid valve switching time.

Generating temperature pulses

The apparatus for generating a temperature pulse in the sample stream is shown in Figure 4. Flow rate was monitored by a rotameter. Temperature pulses were generated by slowly moving a Bunsen burner under the copper coil and then slowly removing it. Pulse amplitude was varied by adjusting the size of the burner flame. Pulse duration was controlled by varying the length of time the burner was under the coil. Temperatures of the influent stream and the reference cell liquid were measured with No. 22 gage copper-constantan butt-welded thermocouples with cold junctions at the ice point.

The second article will describe actual pulse tests carried out on the refractometer's detector cell to determine the dynamic behavior of this component. Additionally, a simplified theoretical analysis will be presented which gives some insight to the pertinent relationships involved. The agreement between theory and experimental results will be discussed.

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1. *REFRACTOMETERS IN PROCESS STREAM ANALYSIS*, L. G. Glasser, "Control Engineering", December 1957.
2. *INSTRUMENT ENGINEERING*, C. S. Draper, W. McKay, and S. Lees, Vol. 2, McGraw-Hill Book Co., Inc., 1953.

J. O. Hougen and G. E. Dreifke were advisors to R. L. Grantom in his 1959 M.S. thesis at St. Louis University, on which these articles are based.

10 mc. ALL SOLID STATE!

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Gate selection and switching of control functions is accomplished by simply applying -12 v dc signal into control input. High frequencies are *not* cabled to switches. Control functions can be performed remotely without special regard to cable length or type, impedance matching, etc. All control functions are brought to rear panel plug. Similar diode and transistor gating techniques are used for high speed switching of input amplifiers and decade counters.

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Higher than vacuum tube models. But you can save the difference on down time in the first year. Model 727A Universal Counter-Timer, $2,750; Model 707A Frequency Period-Meter, $2,575; Model 757A Time Interval Meter, $1,975. Rack mount optional at no extra cost. All prices f.o.b. Sylmar, California.

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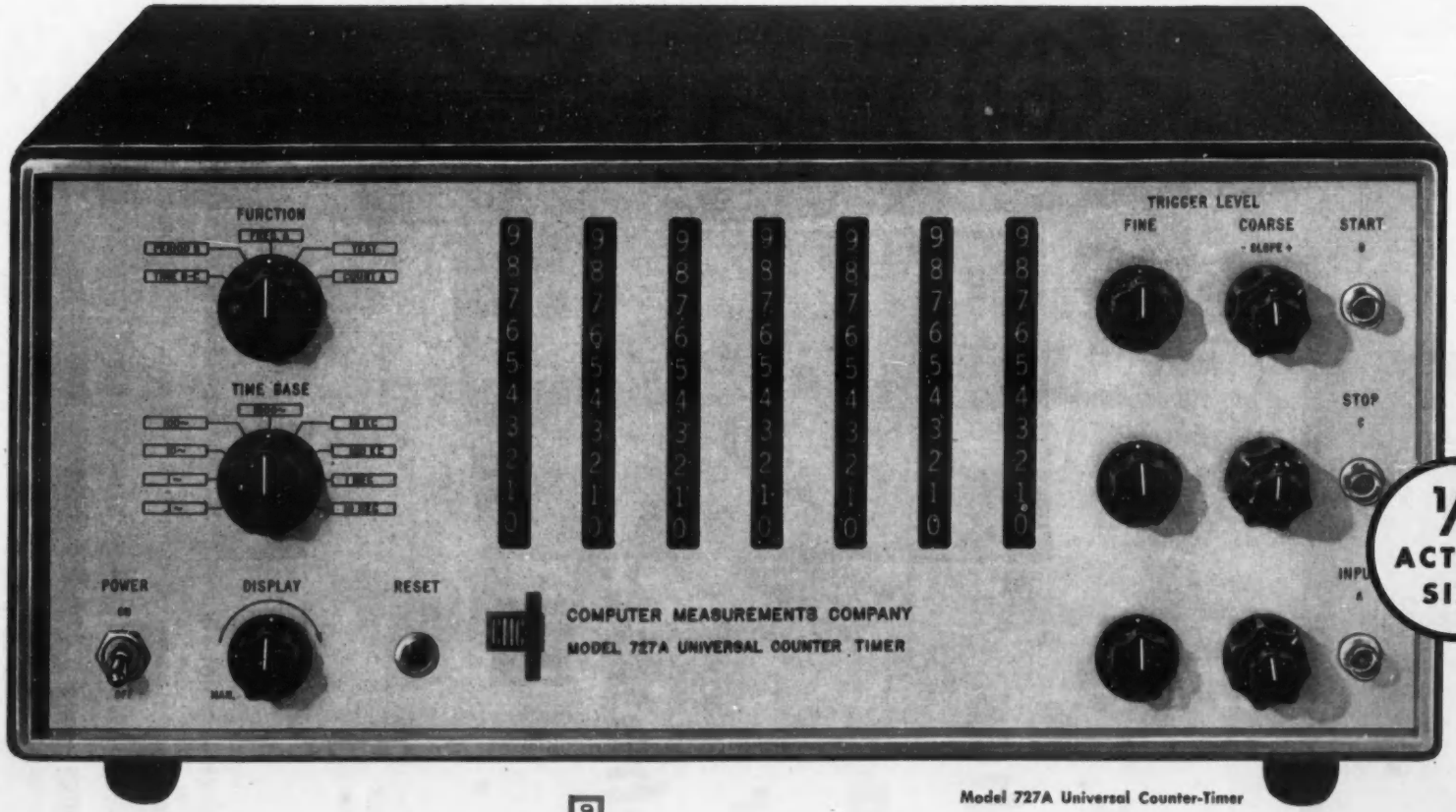

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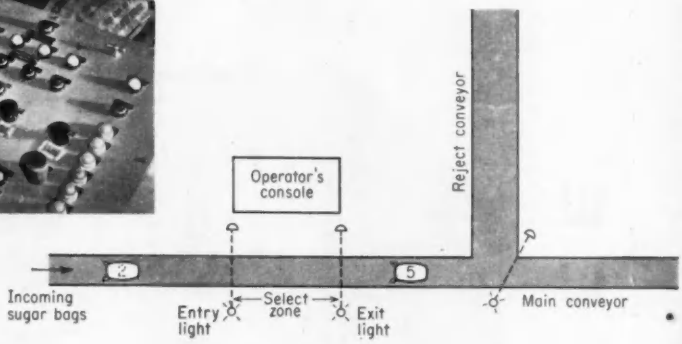
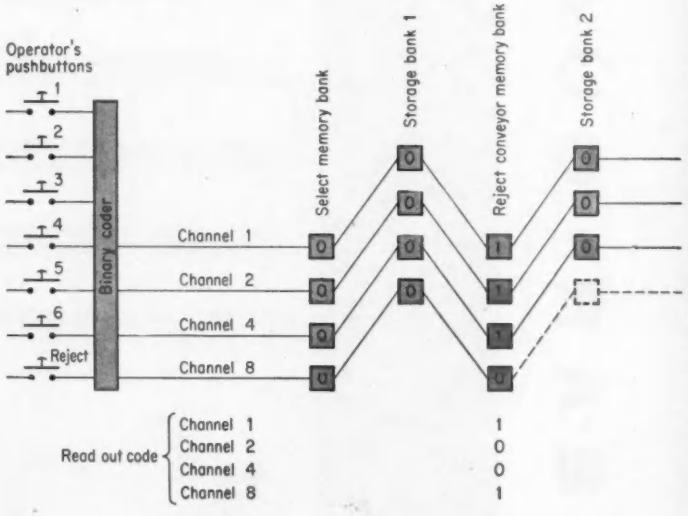


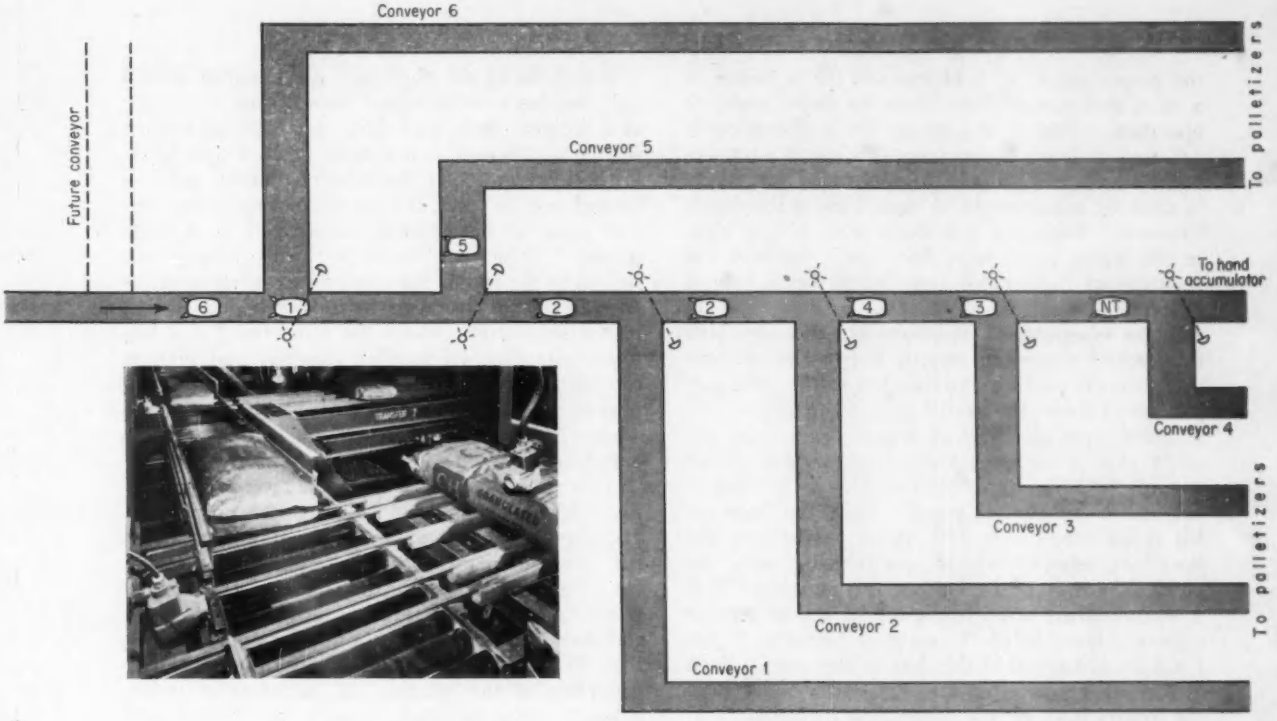
Static Switches Run a Sugar Warehouse

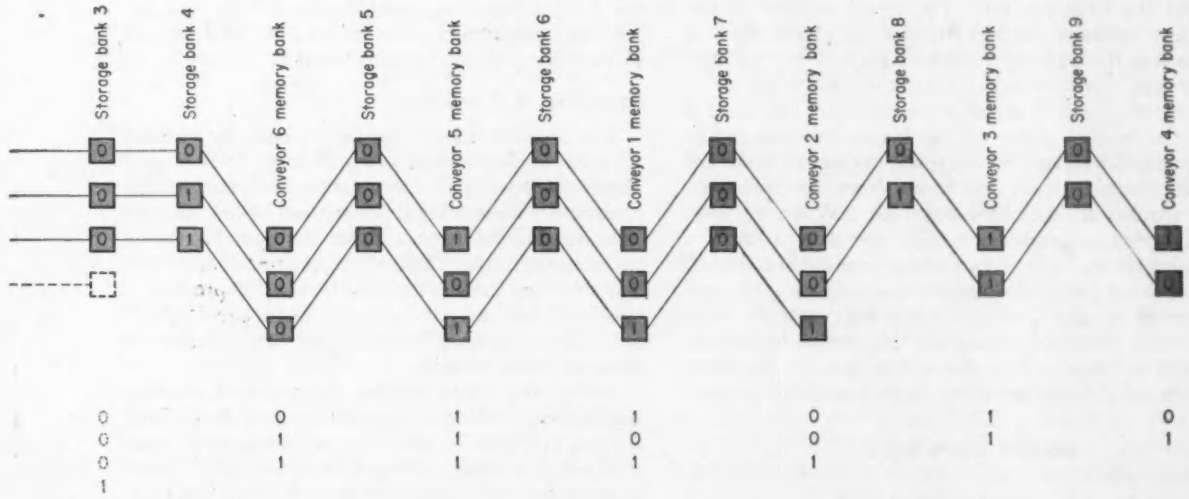
FIG. 1. Operator presses buttons on control panel to select destinations of bagged sugar. Conveyor system is shown here with hypothetical assortment of numbered bags in transit to transfer points monitored by photoelectric cells. Blocks below represent memory elements showing channels and banks in the control system. All memories are off (0) unless a bag is in area.



G. GIACOMELLI
E. BULLOCK
General Electric Co.

Using selective point shift registers, a statically controlled warehousing system sorts bags of different types of sugar one every two seconds. The setup is failsafe, operator-proof, and even takes care of the bags when a conveyor becomes full.





Sugar refineries operate 24 hours a day. This, combined with the high output rate at a large scale refinery, calls for top reliability and long life in a control system to prevent costly material pileups or process shutdown. Add to this the sticky environment problem resulting from sugar dust and the variety of sugar types produced by a full line refiner, and the result is a clear case for static control in a sugar warehouse. Static controls provide the reliability, long life, and ability to operate in adverse environments at C & H Sugar Co. in Crockett, Calif.

At C & H, bagged sugar enters the warehouse from the refinery and must be sorted, palletized, and stored. This line had previously been a manual job because of the variety of products coming from the main feed conveyor. The new system, provided by Lamson Conveyor Corp. with General Electric Co. controls, consists of the main feed conveyor, seven transfer conveyors, and a palletizer for each transfer conveyor.

The system receives a sorting signal from an operator located at the entrance of the warehouse, keeps track of the bags as they are conveyed to their selected transfer conveyors, and transfers them at

the proper point. C & H required that a failure of a pilot device would not cause an out-of-sequence operation. That is, if a device like a photoelectric cell used to detect the presence of a bag at a transfer point should fail, all the bags destined for points beyond the failure might be transferred at the wrong conveyor. Since the conveyors were placed close to the ceiling to conserve floor space, recovery and resorting of misdirected bags would be a tedious chore. This system solves this problem and in addition takes care of situations like that in which the transfer conveyors become full or the operator inadvertently calls for two transfers of the same bag.

Figure 1 shows the overall plan of the system. As different types and sizes of bagged sugar enter the select zone from the refinery, the operator selects one of the seven transfer conveyors by pushing a button on his control panel. Since the bags are fed at random, the control system has to keep the operator's selection signal synchronized with the physical location of the bags on the conveyor. This is accomplished through the use of a shift register system. Shown below the conveyor layout in Figure 1 is a block diagram of the shift register used. Each of the seven inputs fed into the binary coder from the control panel puts a different binary coded signal into the shift register. The signal remains in the select memory bank until the corresponding bag reaches the exit light. The signal is shifted into the first conveyor memory bank when the bag interrupts the light beam of a photoelectric cell located at the transfer point. If the bag is not intended to be transferred at this conveyor, its signal is shifted into the next bank and so on down the line until it reaches its called-for conveyor. When it does, its coded information is read out and initiates a signal that actuates a mechanical transferring device. As soon as transfer begins, the bag's signal—no longer needed—is cancelled out of the shift register. The transfer conveyor carries the bag to an automatic palletizer remote from the sorting system. As other bags enter, their signals are shifted in the same way.

BINARY CODE USED

	Memory Channel				
Code	1	2	4	8	This Code used for:
1	1	0	0	0	This bag not to be transferred
2	0	1	0	0	Transfer at conveyor 4
3	1	1	0	0	Transfer at conveyor 3
4	0	0	1	0	Transfer at conveyor 2
5	1	0	1	0	Transfer at conveyor 1
6	0	1	1	0	Transfer at conveyor 6
7	1	1	1	0	Transfer at conveyor 5
8	0	0	0	1	Transfer at future conveyor
9	1	0	0	1	Transfer at reject conveyor

1—ON
0—OFF

If any one of the photocells' light sources should fail, the bag's coded signal merely shifts through; or if the next bank has a signal in it, the bag's signal will be stored until it can move on to a clear bank. If the light source at the selected transfer point is burned out, however, the bag's signal upon reaching this point is automatically converted to a code (binary 1) which will result in the bag's being carried on to the end of the conveyor to an accumulator area where the bag can be manually loaded. A preventive circuit will do the same thing if a bag reaches its assigned transfer conveyor and finds it too full to accept another bag. Also, if the operator pushes two buttons or fails to make any selection while a bag is in the select zone, the bag will be automatically coded for the manual accumulator area.

A binary code was chosen as the means for identifying the bags. Codes of 1, 2, 4, and 8 provide the necessary coding for the nine required readouts (six numbered conveyors, reject conveyor, provision for a conveyor to be added later, and the manual accumulator area). The Table shows the nine codes and their meanings. It also shows, as does Figure 1, that all four memory channels were used at the beginning of the system. At shift register points down the conveyor, fewer channels are required until the last readout, the manual accumulator area, requires only channel 1. This reduces the total amount of memory channel circuitry needed.

Selecting A Conveyor

The operator selects the binary code by pushing a button on his control panel adjacent to the select zone. Photocells at the entrance and exit of this zone detect when a bag is present and light a "Select" indicator on the panel. After the operator makes his selection, the "Select" light goes out. The operator can cancel his selection by depressing a "Cancel" button. If he does, both the "Select" and "Cancel" lights come on, and the operator can make another selection.

A simplified circuit showing the functions of selecting, coding, and remembering a momentary signal is given in Figure 2. As a bag enters the select zone, a photocell senses its presence, closes contact 1, and keeps it closed as long as the bag is in the select zone. This energizes all of the pushbuttons and gives a signal to the on winding or memory 1. If memories 3, 5, 7, and 9 are off, OR's 10 and 11 will be off, turning NOT 12 on and giving one input to AND's 2, 4, 6 and 8; second input comes from memory 1.

Here's how a transfer conveyor, say conveyor 1, is selected. From Figure 1 or the Table the code for conveyor 1 is seen to be channels 1 and 4. Pressing the button for conveyor 1 produces three different signals via the signal converters shown. One of these goes to the OFF winding of memory 1, but it does not turn off since there is a signal on the ON winding. If the operator pushes two buttons, their signals will add in the OFF winding of memory 1,

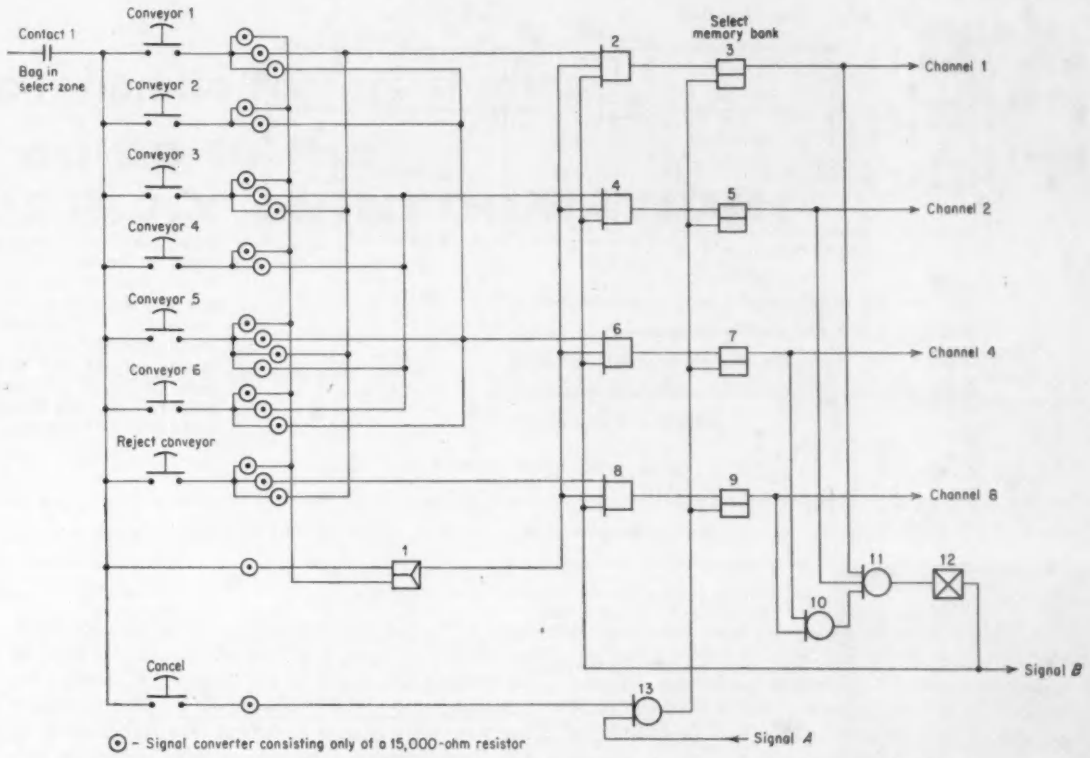


FIG. 2. Operator's choices by pushbuttons are coded in binary coder and shifted into first memory bank. The control system will automatically code a bag for transfer at the end of the line if the operator pushes two buttons at once or no buttons at all.

turning it off and preventing a double selection.

The other two signals from the signal converters on conveyor 1 pushbutton go to AND's 2 and 6, which now have the necessary three inputs each to give outputs, turning memories 3 and 7 on. NOT 12 is turned off, removing one of the inputs to each of the AND's. This keeps new information from turning memories on until all the memories have been reset by a signal from the next memory bank or from the "Cancel" pushbutton. This information is held in the select memory bank until the bag leaves the select zone.

The output of NOT 12 and a signal from the exit photocell combine to enter a code 1 for a bag in case the operator fails to select a conveyor. The exit light signal indicates that the bag is leaving the select zone, and NOT 12's being on signifies that no selection has been made. These two signals are summed in a two-input AND, and the output is fed to an OR between AND 2 and memory 3. This circuit and an associated lockout circuit (so that only one such signal can be inserted for each bag) are not shown in Figure 2.

Setting Up The Memory Banks

The number of shift register banks needed and the type of shift register circuit to be employed were determined first by the number of transfer points (read-outs) needed. Banks were installed between the reject conveyor and conveyor 6 for a possible future need (see Figure 1); they are now simply extra storage banks. The next factor influencing the setup is the maximum number of bags that can be on the conveyor at one time. Dividing the speed of the conveyor, 180 ft per min, by 30, the maximum number of bags to be handled per minute, gives a minimum bag interval of 6 ft on centers. The length of the main conveyor is 64 ft. Dividing this by the bag interval gives 11 for the maximum number of bags that could be on the conveyor. It turns out, however, that this maximum number of bags is not the determining factor for the number of memory banks needed. With a 6 ft minimum bag interval and conveyors spaced only 8 ft apart, it is possible for two bags to be located between two adjacent transfer conveyors. The operation of the system will not abide this; as a bag leaves the photocell-monitored area of a transfer conveyor (for which that bag was not destined), the bag's signal must be shifted into the next bank. (Figure 1 shows two bags on the main conveyor between conveyors 2 and 3.) If there is another bag ahead of it in between conveyors, the following bag's signal will be lost, having no place to go. This means that provisions must be available for storing bags' signals between conveyors; that is, there must be a storage bank

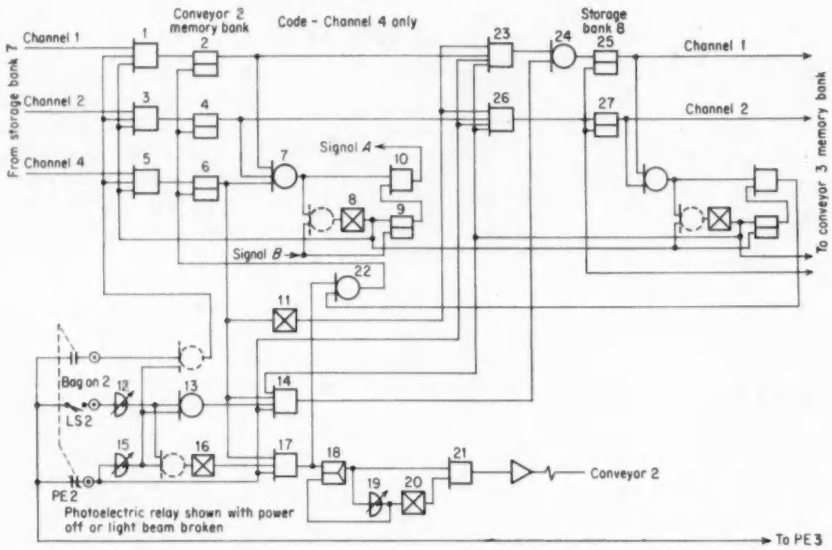


FIG. 3. Transfer at this point, conveyor 2, requires a signal in binary channel 4. If the transfer conveyor is full or if the photocell's light source fails, the bag will automatically be coded for transfer at the end of the line. (A dotted OR symbol indicates an OR function without an OR element.)

between each conveyor's memory bank. In the example of Figure 1, the information for the first bag is stored in conveyor 3 memory bank; the information for the second, in storage bank 8. So the total of memory banks needed is 17, two each for the eight transfer conveyors (counting the one for future addition) and one for the select memory bank.

Selective Point Shift Register

A selective point shift register system (as shown in Figure 3 for conveyor 2 and storage bank 8—elements correspond to blocks of Figure 1) differs from a storage shift register bank in that it will hold the information until a shift signal is received. The operation of the system requires that information be stored until the bags reach transfer points corresponding to the shift register. The control system must allow the information to shift when signaled by the photocells; and when a bag reaches its assigned transfer point, the bag's code must be blocked from shifting further. The storage shift register, on the other hand, stores information only as long as the next shift register bank is full. Note that retentive memories are used in the shift registers to retain the information after a power failure.

In Figure 3 with memories 2, 4, and 6 off, OR 7 will be off allowing NOT 8 to have an output so long as signal *B* is not present. It is not when the preceding bank has information stored. (Figure 2 shows the origin of an equivalent of this signal from NOT 12 in the select memory bank.) NOT 8 will produce an output turning memory 9 on and giving one input each to AND's 1, 3, and 5. A second input comes from the photocell when the light beam is not broken by a bag entering the transfer zone. The other inputs to AND's 1, 3, and 5 are information signals from the respective memory channels. Assuming that channel 4 is the only signal present, AND 5 will be on, which turns memory 6 on. The information is now in the memory bank, so AND's 1, 3, and 5 will be turned off and kept off by turning OR 7 on which turns NOT 8 off, thus removing one input to the AND's. The preceding memory bank is reset to accept new information by OR 7 and memory 9 turning on AND 10 which puts out signal A. This signal resets the preceding memories and remains on until signal *B* arrives to turn off memory 9 and AND 10.

Transferring the Bag

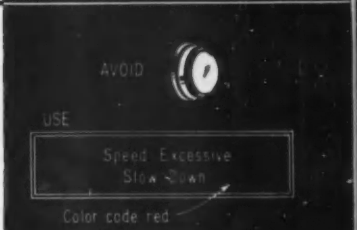
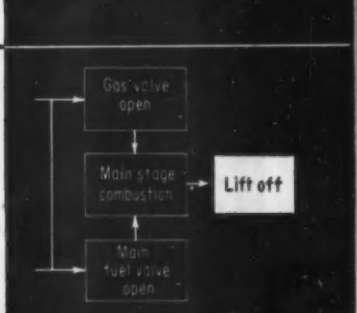
The readout at this memory bank is to actuate transfer at conveyor 2. If the signal is present in channel 4 to turn on AND 5, memory 6 will be turned on. This will give an input to NOT 11 and AND's 14 and 17. Since NOT 11 is off, removing an input from AND's 23 and 26, no information will enter storage bank 8. AND 17 will produce an output when photoelectric relay *PE2* is actuated by a bag and time delays 12 and 15 are not timed out (on state). AND 17 can now turn on memory 18 to give the second needed input to AND 21. This gives an input to the magnetic amplifier which picks up the transfer conveyor solenoid. AND 17 also turns on OR 22, resetting the memories of the shift register bank. When time delay 19 times out, it will turn off NOT 20, resetting memory 18 and removing an input from AND 21.

If at the time of the transfer, limit switch *LS2* has already been held closed long enough to allow time delay 12 to turn on, no bag will be transferred. This means that the transfer conveyor is full. To prevent the transfer, NOT 16 is turned off by time delay 12. OR 13 turns on AND 14, which turns on OR 24. This inserts a channel 1 signal in storage bank 8, so the bag will now be carried to the manual accumulator area. In the event of photocell light source failure, time delay 15 will time out and the same sequence as for a full transfer conveyor results.

from human factors studies . . . . .
a guide to the DISPLAY of INFORMATION

GEORGE A. PETERS
Consultant, Santa Monica, Calif

—for new equipment specifications, use this guide to develop the information content and method of presentation which will yield optimum performance from the human component of the system.

Type of Display	Kind of Information	Specific Example	Human Factors Recommendations	Typical Displays
Performance	Current "doing this"	Engine tachometer	Digital readouts are best for quick and accurate readings. Scales require operator interpretation and tend to clutter the panel, but they are useful for presenting trend information. Pictorial or graphic displays are highly desirable for combining a variety of indicators in an integrated display; however, the display should be an easily recognized and undistorted analog of the situation. **AVOID scales except to show trends USE digital readout** ⇨	
	Command "should be doing this"	Course indicator (desired course)		
	Predicted "will be doing this"	Computed speed (one minute in advance)		
Warning	Emergency "take corrective action"	Fire in right engine	Action-oriented legend lights are better than simple warning lamps. Attention-getting value is increased by color coding (red for emergency and amber for warning), by flashing (3 to 5 times per sec), or by supplementary audio signals. Wire lights to remain on if flashing device fails. **AVOID simple warning lights USE action oriented lights** ⇨	
	Warning "take preventive action"	Fuel leak		
	Caution "watch this"	Engine overheat		
Procedural	Sequential "preliminary step completed; go ahead now"	Torpedo tube ready	Use go—no go indicators or legend lights wherever possible. Attempt to combine displays with controls (as in engraved lighted pushbuttons). Use color coding sparingly to avoid a Christmas tree effect. Spatially organize displays by functional groupings and sequential arrangements. Use only clear, standard abbreviations. Provide press-to-test bulb and circuit features. **USE engraved lighted buttons organized by sequence of operation** ⇨	
	Check "significant change"	Fuel tank #2 empty		
	Supplemental "minor change"	Oil heater on		
Complex	Orientation "the general situation"	Navigation display	Remove all irrelevant information and excessive detailing. Emphasize and integrate the information presented for simple and rapid interpretation, and to make necessary control action readily apparent. General knowledge of the situation plus feedback from prior performance can improve human achievement in complex tasks. **SIMPLIFY complex displays by deleting excess detail** ⇨	
	Instructional "do this"	Check list or manual		
	Evaluative "you are doing this well"	Error indicator		
	Historical "this has been done"	Oscillographic recording		

BASIC BUILDING BLOCKS FROM KEARFOTT

20 SECOND SYNCHRO

This synchro, just one of a broad line offered by Kearfott, provides the extreme accuracy required in today's data transmission systems. Kearfott synchro resolvers enable system designers to achieve unusual accuracy without the need for 2-speed servos and elaborate electronics. By proper impedance, matches up to 64 resolver control transformers can also operate from one resolver transmitter.

TYPICAL CHARACTERISTICS — SIZE 25

	Transmitter	Control Transformer
Type Resolver		
Part Number	Z5161-001	Z5151-003
Excit. Volts (Max.)	115	90
Frequency (cps)	400	400
Primary Imped.	400/80°	8500/80°
Secondary Imped.	260/80°	14000/80°
Transform. Ratio	.7826	1.278
Max. Error fr. E.Z.	20 seconds	20 seconds
Primary	Rotor	Stator

Write for complete data.

BASIC BUILDING BLOCKS FROM KEARFOTT

PRECISE ANGLE INDICATOR

Consisting of an angle position indicator, motor and servo amplifier, this small, versatile, rack panel mounted unit provides angular position indications for laboratory, production and field use. Input signals proportional to unknown angular position of synchro device being measured are resolved as an error voltage, which is amplified and used to drive an internal servo loop to null. Counter mechanism then provides direct visual readout of angular position.

TYPICAL CHARACTERISTICS

- Input Signal: S_1, S_2, and S_3 of external synchro transmitter.
- Repeatability: Within 0.6 minute in either a clockwise or counterclockwise direction for any angular position.
- Readability: 0.5 minute through full range from zero to 360° Rotation is continuous.
- Accuracy: ± 6 minutes in the standard unit. Other accuracies available on request.
- Sensitivity: 0.5 minutes maximum.
- Slewing Speed: Phase sensitive, 180° in 7 seconds.
- Input Voltages: 115 volts, single phase, 400 cycles, 23 VA max.
- Size: Standard Rack Mounting— 1¾" x 9½" x 8½"

Write for complete data.

BASIC BUILDING BLOCKS FROM KEARFOTT

FLOATED RATE INTEGRATING GYROS

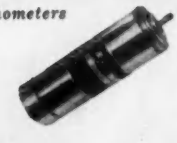
Specifically designed for missile applications, these Kearfott miniature gyros operate efficiently at unlimited altitudes. Their outstanding accuracy and performance make them superior to any comparably-sized units on the market. Hermetically sealed within a thermal jacket, these gyros are ruggedly designed and completely adaptable to production methods. Performance characteristics that are even more precise can be provided within the same dimensions.

TYPICAL CHARACTERISTICS

- Mass Unbalance:
  - Along Input Axis: 1.0°/ hr maximum untrimmed
- Standard Deviation (short term):
  - Azimuth Position: 0.05°/hr
  - Vertical Position: 0.03°/hr
- Drift Rate Due to Anisoelasticity
  - Steady Acceleration: .015°/hr./g² maximum
- Vibratory Acceleration: .008°/hr./g² maximum
- Damping:
  - Ratio of input angle to output angle is 0.2
- Characteristic Time: .0035 seconds or less
- Weight: 0.7 lbs.
- Warm-Up Time: 10 minutes from –60°F
- Life: 1000 hours minimum

Write for complete data.

Tachometers



Servo Valve

Ferrites

KEARFOTT DIVISION
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OPTIMUM RESPONSE RELAY SERVOS

PART I: Evolution of the Optimum Switching Criteria

THE GIST: At the request of CONTROL ENGINEERING, author Lewis has summed up in a three-part series all of the important design techniques that have been used to optimize the response of relay servos. In this first part he reviews the operation of elementary relay control, describes the gradual development of the optimum switching criteria, and points out the difficulties which hamper its direct application. Parts II and III will provide detailed descriptions of the methods used to overcome these difficulties. Heavily referenced, each article in the series serves a twofold purpose: to rapidly orient the newcomer and to provide a source of detailed studies for those wishing a more complete understanding of the problems.

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Although relays have served as control elements in feedback systems for over 25 years (Ref. 1), the accelerated interest in such systems during the early Forties led to further analysis (Ref. 2), application of the phase-plane technique (Refs. 3, 4), and introduction of the describing function method (Ref. 5).

In many applications these relay control systems offered the advantages of simplicity, relatively large power handling ability, and low cost. Their inherent nonlinearity, however, forced a departure from the simple analytical techniques used for linear systems. Investigations of phenomena such as limit cycles and the dependence of response characteristics on input amplitude produced considerable information on the design of elementary (on-off) relay control systems. Finally, within the last decade the concept of optimum response has evolved and with it techniques for achieving even better performance.

Development of these improved systems involves:

- Specification—stating the type of input to be used, the output member to be controlled and defining optimum performance
- Design and synthesis—deriving switching boundaries and calculating numerical values
- Analysis—investigating stability conditions, speed of response, error, and other special characteristics of the designed system
- Instrumentation—choosing actual components and checking design feasibility regarding performance, cost, and reliability
- Test—fabricating and testing the prototype

The sequence of these five steps may vary, but each is an important part of the complete design.

In terms of specification, the scope of this survey of techniques for designing optimum relay control systems may be outlined as follows (where the controlled variable is assumed to be an output position and the ideal controller a two- or three-position relay plus a switching computer with or without compensating networks):

A. Input types include 1) step functions of position, 2) ramp functions of position, 3) periodic functions, and 4) random inputs.

B. Output members include linear members characterized by transfer functions of the form $1/s^2$, $1/s^3$, $1/s(\tau s + 1)$ or $1/s^2(\tau s + 1)$.

C. Optimum performance, for the first two types of inputs as well as for low frequency periodic inputs, requires that the error and its derivatives be reduced to zero in minimum time, taking into account component limitations; for higher frequency periodic inputs other definitions may be used.

These cover the major areas of published studies although some results have been given for systems which fall outside these restrictions, e.g., those with coulomb friction in the output members (Refs. 6, 7) and those using multiposition switches (Ref. 8).

As a logical introduction to optimum relay systems, this first part of the series will review briefly the major analytical and graphical methods used to study elementary relay systems and then describe the theory behind the optimum response approach.

Elementary Relay Control System

The block diagram, Figure 1, represents the familiar elementary relay control system, and for a

simplified output motor and load, the differential equation relating output position to torque is:

$$J\ddot{c} + F\dot{c} = T \tag{1}$$

where J is the total output moment of inertia, F the equivalent viscous friction constant, c the output position, and T the developed torque. The output member transfer function $c(s)/T(s)$ is then:

$$\frac{F^{-1}}{s\,(\tau s + 1)} \tag{2}$$

For an ideal relay the relation between torque and error may be expressed as follows:

$$T = KV \operatorname{sgn} e \tag{3}$$

where K is a torque constant, V is a constant applied voltage, and signum e is $+1$ for $e > 0$, -1 for $e < 0$, and 0 for $e = 0$. Switching of the ideal relay then depends only on the sign of the position error.

Three methods of analysis have been used for this type of system. In the first, piecewise linearity makes it possible to solve Equation 1 for known inputs. If for example, r is a step input of position or velocity, analysis yields the usual transient response. Hazen, Kahn, and more recently, Macmillan (Refs. 1, 2, and 9), have presented methods based on this idea; the time response of the system is an end result of the analysis. In the second method the phase plane has been used to describe the system behavior for the same types of inputs; MacColl and Weiss (Refs. 3 and 4) have shown the resulting trajectories. From these the time responses can be computed if required. The third approach is the method of describing functions (Ref. 5). Here a sinusoidal relay input is assumed and system characteristics presented as amplitude- and frequency-dependent loci in the complex plane. Frequency response of a linearized system is the result.

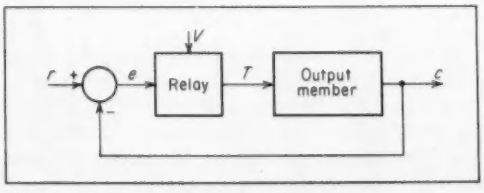

FIG. 1. Elementary relay control system.

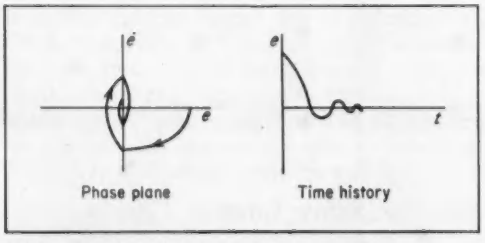

FIG. 2. Typical phase-plane trajectory and error-time response for the system of Figure 1.

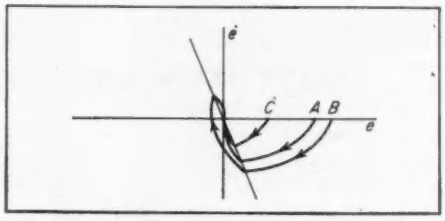

FIG. 3. Modified switching boundary improves design flexibility.

Phase-plane approach most useful

Each of these methods suits a certain purpose and each uses both analytical and graphical techniques. For the purpose of discussing optimum relay systems, however, familiarity with the phase-plane method is essential since most attempts at synthesizing optimum systems have been based on desirable trajectories and switching boundaries in the phase plane. It is also necessary to relate phase-plane trajectories to the corresponding time responses. Gibson and Truxal provide concise discussions of the phase-plane technique (Refs. 10 and 11).

Figure 2 shows a typical phase-plane trajectory and error time response for the system described by Equations 1 and 3, subjected to a step input of position. Note that the system tends toward zero error but that several torque reversals are required. The switching boundary is the $\dot{e}$-axis of the phase plane.

A more general analysis of positional relay control systems by Flugge-Lotz (Ref. 12) includes in Equation 1 a term proportional to position:

$$J\ddot{c} + F\dot{c} + Gc = T$$

or with $r = 0$,

$$J\ddot{e} + F\dot{e} + Ge = -T \tag{4}$$

This produces a different output member transfer function, and, more important, the equation describing the operation of the relay now contains a term proportional to error rate:

$$T = KV \operatorname{sgn} (e + \rho\dot{e}) \tag{5}$$

As shown in Figure 3, the switching boundary now consists of a straight line through the origin making an angle (dependent on ρ) with the $\dot{e}$-axis. The figure also shows three possible response trajectories for a step input of position to the original system of Equation 1. Of the three, only the A trajectory reaches equilibrium with a single torque reversal. Unfortunately, other input amplitudes (B and C) yield less desirable types of response. The result of using a modified switching criterion (Equation 5) indicates, however, an increased flexibility in the design of relay control systems.

Before getting into the concept of optimum response, consider first some of the relay imperfections which cause departures from the performance of an ideal relay. For example, the effects of relay dead zone and hysteresis have been studied in detail and, for a system with an output member described by Equation 2, either can cause sustained free oscillations under certain input conditions. Time delay

in making the actual torque reversal also changes the character of the response, and for the output member of Equation 2, its effect is similar to that of hysteresis. Various combinations of dead zone, hysteresis, and time delay have also been studied. In general, dead zone is the most objectionable; in fact for some systems small hysteresis and time delay effects may even be desirable. Several published analyses (Refs. 12, 13, and 14) explain these effects in terms of phase-plane trajectories. Another shows how feedback from the relay itself can be used to eliminate the effects of time delay and hysteresis (Ref. 15). A general analytical method for designing relay servos for deadbeat (no overshoot) response to a step input has been described by Hart (Ref. 16).

In one investigation of an elementary relay control with sinusoidal input, responses ranged from an unsatisfactory large oscillation close to the input frequency (similar to resonance) to a satisfactory response characterized by small oscillations at the dead zone boundaries (Ref. 17). A single empirical parameter, a function of input amplitude and frequency, was found to be a satisfactory indicator of the type of response that could be expected. Since time appears explicitly in the equations, phase-plane techniques become difficult in this type of investigation, and an analog computer study is usually preferred. Use of compensating networks (Refs. 5 and 18) and the familiar *R-C* lead network also improve performance of the elementary relay system. This is essentially an extension of frequency response concepts. Modification of the switching boundaries, using approximate error plus error rate, also can be interpreted directly as changes in the time response.

Theory of Optimum Response

The review above showed that when the elementary relay system was subjected to a step input of position, it required several torque reversals to reach equilibrium. For the same second order system with a modified switching boundary, performance improves at a particular input amplitude. An optimum response of this type of system to a step input was suggested about 10 years ago (Refs. 19, 20, and 21) and was soon extended to more complex systems (Ref. 22). Minimum-time response is the desired performance, but this is subject to certain limitations in the output member such as maximum velocity and acceleration.

As a system changes state or moves from one point to another along the phase-plane trajectory, elapsed time may be expressed as follows:

$$t_{1,2} = \int_{e_1}^{e_2} \frac{de}{\dot{e}} \tag{6}$$

Thus in Figure 4A, minimum response time requires that the shaded area in the (e, $1/\dot{e}$) plane be minimized. Figure 4B shows an optimum response trajectory for an output member with transfer function of the form $1/s^2$ (i.e., output inertia only); it illustrates the effect of acceleration or torque saturation. Because of its simplicity, this particular example often serves as a starting point for analyzing optimum relay systems. Actually, it is a simplification of the system of Equation 1; i.e., $F = 0$ so that there is no velocity limitation. Physically Figure 4B may be interpreted as follows: the output member accelerates under maximum torque for the first part of the transient; torque reversal or switching occurs at point *x*; the output member decelerates in the same way until the trajectory reaches the origin where torque is removed.

Response as a function of time, phase trajectories, and switching boundary for optimum performance are readily determined for this example. From Equation 1, with $F = 0$,

$$\ddot{e} = KV/J \quad \text{during acceleration,}$$

and

$$\ddot{e} = -KV/J \quad \text{during deceleration}$$

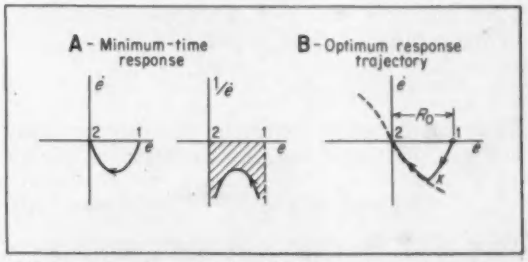

FIG. 4. Phase-plane sketches illustrating A—minimum-time concept and B—typical optimum response trajectory for a system with acceleration limiting.

For a step input $\ddot{e} = -\ddot{\theta}$, these relations become:

$$\ddot{e} = -KV/J \tag{7a}$$

and

$$\ddot{e} = KV/J \tag{7b}$$

Integrating Equation 7a and imposing the condition $\dot{e} = 0$ at $t = 0$ yields:

$$\dot{e} = -\frac{KV}{J}t \tag{8}$$

Integrating again and using a positive step input of $r = R_0$,

$$e = -\frac{KV}{2J}t^2 + R_0 \tag{9}$$

Solving for t in Equation 8 and substituting this value in Equation 9 gives:

$$e = -\frac{J}{2KV}\dot{e}^2 + R_0 \tag{10}$$

Equations 7a, 8, and 9 describe the response as a function of time, and Equation 10, the parabolic trajectory during the first part of the transient, i.e., points 1 to *x* in Figure 4B. For optimum response the trajectory after switching must pass through the origin, and Equation 7B is used for the torque reversal condition. Thus the equation describing the

trajectory from points x to 2 may be written:

$$e = \frac{J}{2KV}\dot{e}^2 \tag{11}$$

Simultaneous solution of Equations 10 and 11 gives the value of $e = R_0/2$ at the common point x; Equation 9 can then be used to find the time required to go from point 1 to x:

$$t_{1,x} = \sqrt{\frac{J}{KV}}R_0 \tag{12}$$

Finally, for $t_{1,2} = 2t_{1,x}$, the time responses during deceleration are:

$$\dot{e} = -\frac{KV}{J}(t_{1,2} - t) \tag{13}$$

and

$$e = \frac{KV}{2J}(t_{1,2} - t)^2 \tag{14}$$

Figure 5 illustrates the responses for this system. The equation of the switching boundary in the fourth quadrant of the phase plane is the same as Equation 11, thus *the switching boundary is the trajectory* through the origin. This has been called a zero trajectory (Ref. 23). The switching boundary in the second quadrant is obtained similarly, i.e.,

$$e = -\frac{J}{2KV}\dot{e}^2 \tag{15}$$

Thus for the entire switching boundary as shown in Figure 4B, torque and error are related as follows:

$$T = KV\,\mathrm{sgn}\left(|\dot{e}|\dot{e} + \frac{2KV}{J}e\right) = KV\,\mathrm{sgn}\,\sigma \tag{16}$$

where $|\dot{e}|\dot{e}$ is the absquare or signed square of $\dot{e}$.

Interpretation of this equation requires some care since the switching boundary is now the trajectory. In Equations 3 and 5 this was not the case, and the system representative point alternated between regions of positive and negative torque. In this example, however, σ is positive for the first half of the transient but ideally zero during the latter half of the transient when decelerating torque is desired in order to reach equilibrium.

Other types of output members

Several published studies (Refs. 6, 24, and 25) on optimum first and second order relay systems provide time responses and switching boundaries for output members with widely different transfer function forms.

For first order systems Equation 3 establishes the optimum switching boundary, $e = 0$; for the first two second order systems optimum switching boundaries resemble that of Figure 4B. For the system in which $0<\zeta<1$, the switching boundary is complicated by the multiple intersections of the two sets of trajectories (Ref. 25), and several torque reversals may be needed to reach equilibrium.

In considering these other output member forms it is important to state the input for which response is optimum. Emphasis in the example cited was on dynamic performance, and under ideal conditions, steady state error is zero and the location of the

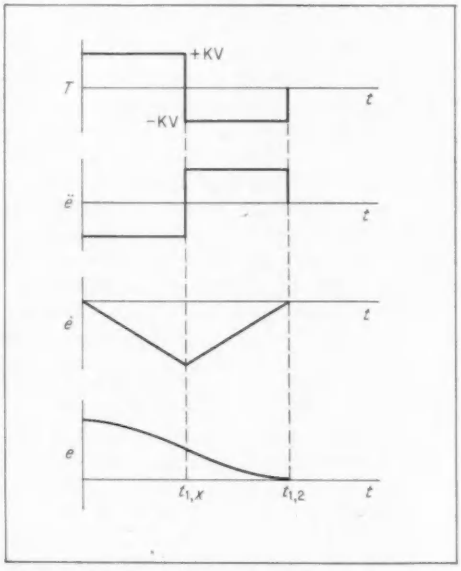

FIG. 5. Optimum time responses of torque, acceleration, error rate, and error.

switching boundary is independent of input amplitude. This is not true for all second order systems even when subjected to step or ramp inputs. In many studies input r is assumed to be zero, and optimum response is obtained only for initial values of e and $\dot{e}$. As an example of this difficulty, suppose the output member of Equation 1 is used in a system subjected to a ramp input $r = R_1 t$, where R_1 is less than runaway speed. Now Equation 1 becomes:

$$J\ddot{e} + F\dot{e} = FR_1 - KV \quad \text{(during deceleration)} \tag{17a}$$

or

$$J\ddot{e} + F\dot{e} = FR_1 + KV \quad \text{(during acceleration)} \tag{17b}$$

Now if $\dot{e}(d\dot{e}/de)$ is substituted for $\ddot{e}$ and the expressions for de are integrated, the trajectory equations become:

$$e = C_1 - \frac{J}{F}\dot{e} - \frac{J}{F}\left(R_1 - \frac{KV}{F}\right)\ln\left|\dot{e} - R_1 + \frac{KV}{F}\right| \tag{18a}$$

and

$$e = C_2 - \frac{J}{F}\dot{e} - \frac{J}{F}\left(R_1 + \frac{KV}{F}\right)\ln\left|\dot{e} - R_1 - \frac{KV}{F}\right| \tag{18b}$$

where C_1 and C_2 are arbitrary constants. Starting point $(0, R_1)$ conditions may be used to evaluate C_1 and origin $(0, 0)$ conditions to evaluate C_2 since this should be a zero trajectory. The switching boundary in the fourth quadrant then becomes:

$$e = -\frac{J}{F}\dot{e} + \frac{J}{F}\left(R_1 + \frac{KV}{F}\right)\ln\left[\frac{\left|R_1 + \frac{KV}{F}\right|}{\left|\dot{e} - R_1 - \frac{KV}{F}\right|}\right] \tag{19}$$

and *this is a function of* R_1. The boundary in the second quadrant is found from Equation 18a in the same way, and if $R_1 = 0$, a symmetrical boundary results. Figure 6 shows the complete switching boundary and a typical trajectory. Note the behavior of this system at the origin. If, as in the previous example, torque is removed at the origin,

the system representative point tends to enter the first quadrant since, with $R_1 \neq 0$, equilibrium cannot exist. However, switching would immediately occur, and the sequence of acceleration and deceleration would repeat. This is exactly what happens in an actual system; dead zone and time delay produce an oscillation with average values of e, $\dot{e}$, and torque.

Hardware limitations

Again this emphasizes the need for recognizing the actual relay characteristics; during early design stages the ideal system is useful, but dead zone, time lag, and hysteresis effects must be checked. Furthermore, in an optimum relay system where switching boundaries must be physically instrumented, the effects of measuring errors, computational errors, and uncertainties in the output member parameters must be investigated. Noise in the signal that actuates the relay is also a potential source of trouble. Kazda (Ref. 7) has demonstrated the effect of time delay for the system of Equation 7; in this study curves relate the error rate intercept (distance from the phase-plane origin to the trajectory intersection on the $\dot{e}$-axis) to the actual delay time. The effect of varying the switching boundary of this system has also been studied by combining Equations 11 and 15 as $e = -k\dot{e}|\dot{e}|^{a-1}$ and then investigating changes in response time for variations in k and a (Ref. 26). Variations in k are called "location errors"; those in a (Ref. 26). Variations in k are called "location errors"; those in a, "shape errors". In general, it appears that errors which produce damped oscillatory motion are less desirable than those which produce no overshoot.

In other studies investigators have regarded the existence of any friction as a parameter error and have looked into the effects of both viscous and coulomb friction (Refs. 7, 6). A study by Oldenburger (Ref. 27) revealed that wide variations in the parameter of the control signal equation (over 2 to 1) could be tolerated.

Next—putting the Theory to work

The foregoing has reviewed briefly the elementary relay control system, the logical development of the optimum response theory, and some of the difficulties encountered when actual instrumentation of the theory begins. Because of these physical limitations and other problems, many attempts have been made to build relay control systems which approach optimum performance other than by means of the optimum switching criteria. These related systems, as well as those which directly implement the optimum switching criteria, will be classified and discussed in the next two parts of this series.

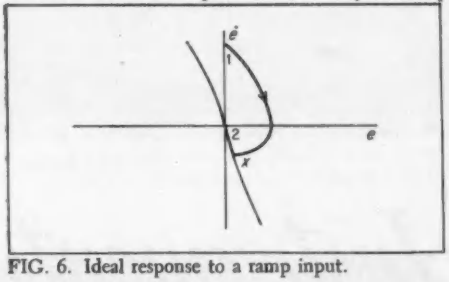

FIG. 6. Ideal response to a ramp input.

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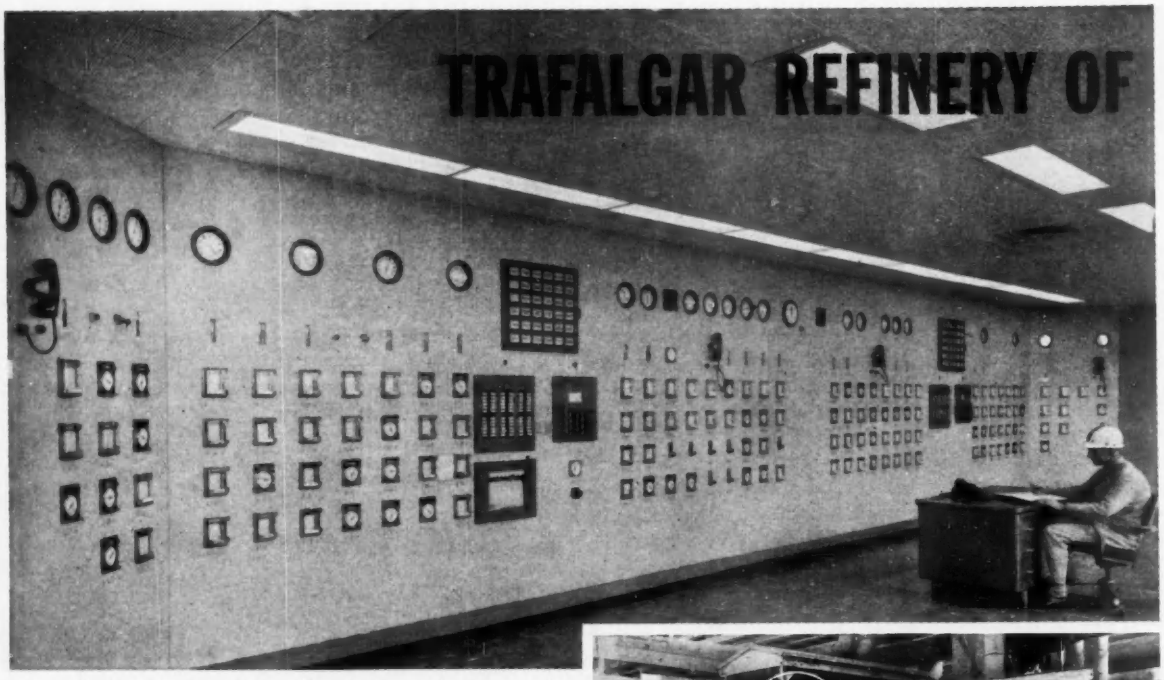
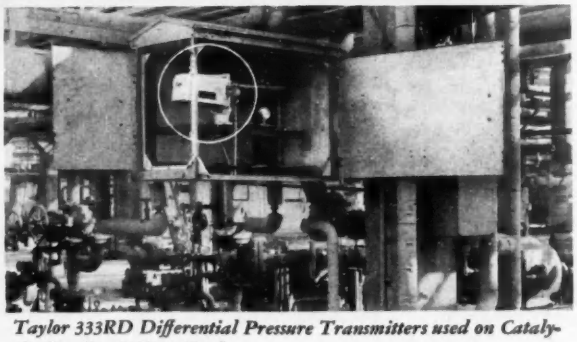
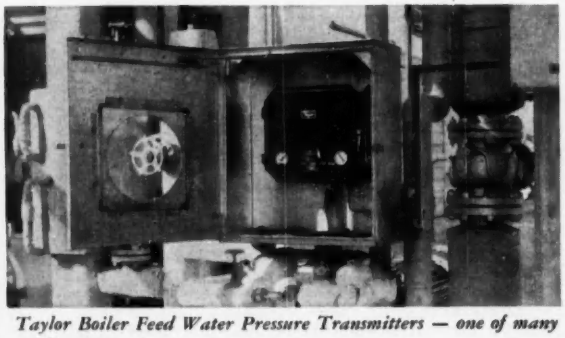


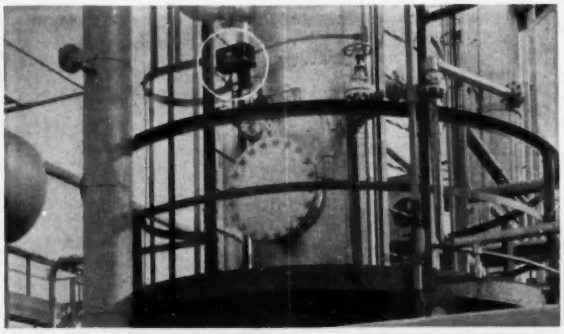
Centralized Taylor Control Panel for the four main process units at Trafalgar: (1) Crude Fractionation, (2) Catalytic Cracking, (3) Gas Plant, (4) Catalytic Reforming.



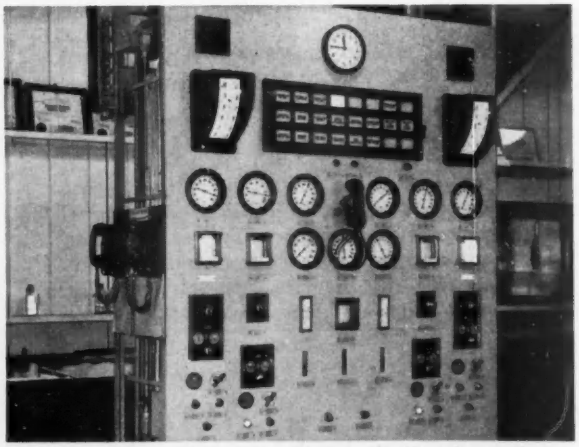
Taylor 333RD Differential Pressure Transmitters used on Catalytic Gasoline Splitter Feed.



Taylor Boiler Feed Water Pressure Transmitters — one of many applications.



TRANSAIRE Temperature Transmitter — installed on Catalytic Gasoline Splitter column bottoms.*



Utility control panel for power plant at the Trafalgar refinery.

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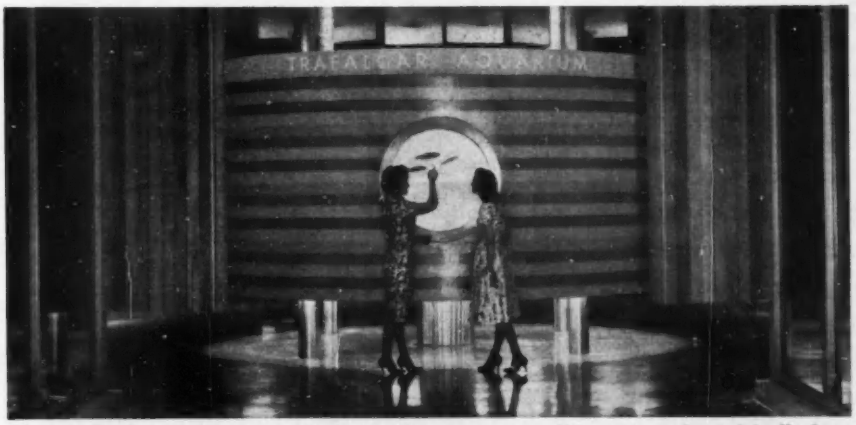

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The Taylor control panel for the Trafalgar water treatment plant.

MEAN ACCURACY FIRST

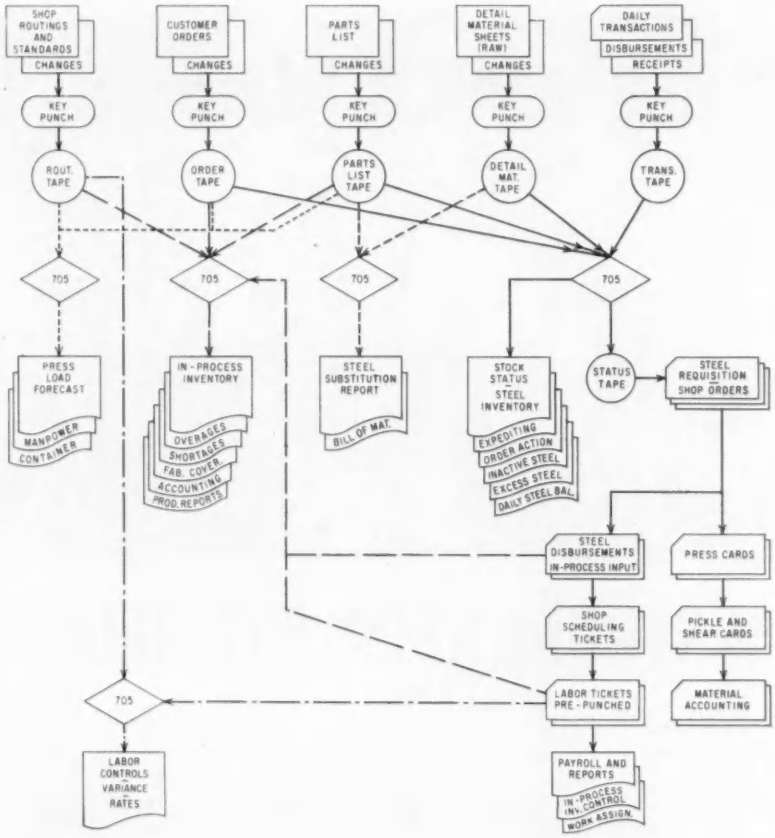

FIG. 1. Simplified flow chart of overall 705 production control system.

Manufacturing Control With a 705

J. M. CHERBA, Manager Production Controls
Automotive Div., A. O. Smith Corp.

THE GIST: A. O. Smith uses an IBM 705 computer to control its production of automotive parts. Specific flow charts show how up-to-the-minute data helps reduce inventory requirements in stock and in the process itself, how substitute steel sizes are computed to efficiently reduce obsolete or excess inventory, and how accurate machine load and manpower requirements are forecast to help smooth production load fluctuations and avoid expensive overtime.

Since 1957 the IBM 705 electronic data processing machine at A. O. Smith Corp. has been continuously producing data for controlling the manufacture of automotive parts. The program was begun with the decision to mechanize all operations in the Steel Procurement Dept., including the ordering of steel. The setup has been operating for one year, with the 705 system running parallel to the old.

But another project was started and completed during the development of the steel procurement program. Because it was considered urgent, a press load program was written for the 705 which permits the Automotive Manufacturing Control Dept. to produce a press load forecast in less than two days. On punched card machines the former version of the press load forecast took at least two weeks. Also, two other projects for manufacturing control are complete: a steel substitution program and a manpower requirements report. Programs for in-process inventory control are planned, and preparation of labor control reports has been completed. Parts scheduling and container requirements will be tackled later on.

Figure 1 is a simplified summary flow chart of

the 705 production control system. It shows only the input data and the output in the form of punched cards or reports for the various manufacturing control programs mentioned above. These programs overlap in that the same data may be used as input to several of them. A more detailed flow chart for each of the programs will be explained below.

As shown in Figure 1 the input data to the overall system consists of shop routings; customer orders; parts lists; detailed material sheets, including raw material needed to make parts; and daily transactions such as receipts, disbursements, steel requisitions or reservations, scrap tickets and adjustments, and all changes to input data files. All of the input data are keypunched onto cards and processed into magnetic tape format for use by the 705. All tape files are kept updated by the 705 daily or as necessary.

To prepare a steel procurement stock status report, for example, the 705 will select the updated customer order tape, the parts list tape, the detail material tape, the daily transactions tape, and the previous balance tape. These data can be processed to produce a number of other tapes and reports: present steel inventory; steel planning; and various management by exception reports such as expediting, order action, inactive steel, obsolete steel, excess steel, and steel reservations and requisitions. The steel requisition can then be used to produce other documents necessary to shop operation such as preprinted and prepunched press cards, pickle and shear cards, Sched-U-Graph tickets, material accounting tickets, disbursements, and labor tickets.

THE MATERIAL CONTROL PROGRAM

To take a specific case of an individual application within the manufacturing control program, consider the material control program. The concept of complete and accurate input information is extremely important to inventory control systems, whether raw material, in-process, or finished goods inventory. A great deal of effort was spent during two years to create accurate input data for all present and proposed data processing applications.

The basic input to the material controls application consists of information from engineering control on the parts used, called the parts list master file, and information from steel standards on the steel to be used to make these parts, called the detail material sheets master file. Both of these master files are maintained on magnetic tapes and updated every week. The parts list identifies a frame assembly or subassembly and contains all the component parts necessary to the manufacturing of these assemblies. The detail material sheets master file must also be accurate and up-to-date because there may be changes in steel sizes or weights of the parts, the quantity of parts to be made out of the sheet of steel, etc. Inaccuracies could lead to ordering the wrong material, the wrong amounts, or not ordering at all.

Figure 2 is a simplified flow chart of the material control program. The basic input data just described are merged through the 705 to obtain a bill of material master tape by matching part for part with the two files. Along with the bill of material, the 705 also prints a where-used report which is a printed form of the make-up of the bill of material. An exception report is created at the same time called the bill of material missing list, which is used to locate parts missing from either master file due to obsolescence, lag in file maintenance, or error. These reports are not shown in Figure 2. The bill of material tape itself is sorted in assembly number sequence by the 705 for the second computer run which is called the parts requirements explosion program.

The second computer run uses the bill of material as input, plus the definite and forecasted customer orders and schedule changes such as increases, decreases, redates, and cancellations. The main output is the raw material requirements tape which contains all the parts needed to fill the customer's order for an assembly and the size and quantity of steel needed to make the part, plus all scheduled changes for each part. The requirement tape also contains the assembly data needed to complete and ship each part on time. During this program the 705 also creates a purchased parts requirement report for the Purchased Parts Dept. to aid in ordering and expediting.

A part can be identified with the correct steel size because of the bill of materials merge. But if gage, width, and length are used, there are 1,200 different sizes. To simplify this identification problem for the 705, each size is given an eight-digit code number called an item number. The parts requirements tape is sorted in item number (or size) sequence to be merged with all the other transactions involved in the material control application. Each of these (shown as input cards across the top right-hand side of Figure 2) has a separate system of its own. The main material control program then produces as its main output the master tape file of all raw material inventory. This is the stock status master tape which contains a record of each size in item number sequence. This master tape is updated by the 705 daily using the old master as input in addition to all daily transactions. The nucleus of all management exception reports and prepunched tickets is the 705 stock status report, whose form is shown with part of a daily transactions report in Figure 3. With these two reports the operating personnel in the Steel Procurement Dept. have by 10:30 a.m. a complete, detailed record of each steel size and the activity revolving around it up to 7:00 a.m. the same morning.

The main material control program also produces a number of other reports for management use which are shown in Figure 2. For example:

Order action report—The amount to be ordered is

the amount of the negative planned inventory; order date is computed to maintain a 30-day inventory.

Obsolete and inactive material report—This report contains all material that is definitely known to be obsolete and all material that is determined to be inactive. Material becomes automatically inactive if there has been no requirement for that material for a period of three months. The report will show any open orders or extended requirements for inactive material, the amount on hand, and the number of weeks of no action.

Excess report—Material in excess of a 30-day inventory will appear on the excess report which shows the amount of material in excess and its value.

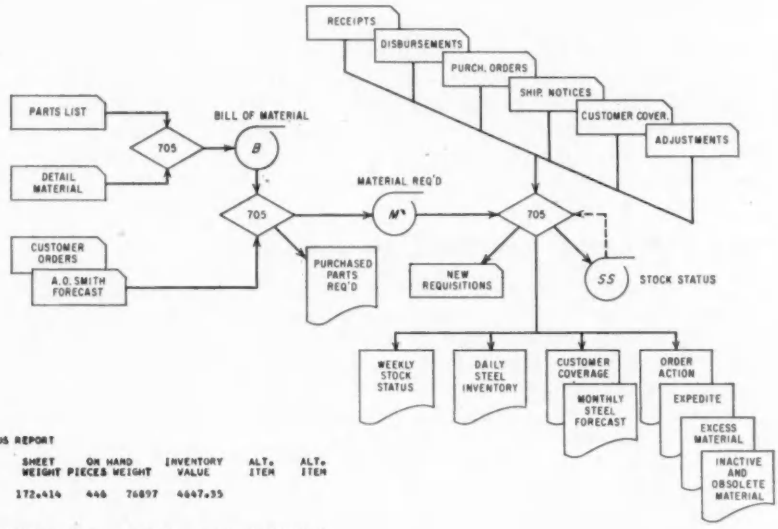

Fig. 2.
Simplified flow chart of system used for controlling material in stock. Main output is the stock status tape, which is updated every day.

STOCK STATUS REPORT

ITEM NO	SPEC	GAUGE	WIDTH	LENGTH	TYPE	SHEET WEIGHT	ON HAND PIECES	ON HAND WEIGHT	INVENTORY VALUE	ALT. ITEM	ALT. ITEM
60303200	1110	.17900	40	85	SHEET	172.414	446	76897	4647.35		

PART NO. PREF	NO	SUFF	CUST	PCS OUT	B/M	P/B	S	PART NO. PREF	NO	SUFF	CUST	PCS OUT	B/M	P/B	S	PART NO. PREF	NO	SUFF	CUST	PCS OUT	B/M	P/B	S
CM	1193	10	BUIC	150	2	1	0	CM	1194	10	BUIC	150	2	1	0								

DATE	PART NO. PREF	NO	SUFF	RUN NO.	STEEL REQT	AMT COV	TOTAL REQT	TOTAL COV	SUB/STD ITEM NO	REQSN AMT	PURCH ORDER	MILL CODE	ORDER QTY	ORDER BAL	QTY I.T.	AVAIL INV	PLANNED INV
12/06											36208	INL	781	390		446	836
01/09	CM	1193	10	3240	204					204						242	632
01/09	CM	1194	10	3242	204					204						38	428
01/10											38671	INL	216	210		38	646
																32	640
																20	628
																20	424
																20	220
																20	16

DAILY TRANSACTION REPORT

ITEM NO.	PART NUMBER			P.O. NO.	TRANSACTION	MILL	ITEM NO.	QUANTITY OF ORDER	FROM	TO	COVERAGE	COMMENTS
60600750				32560	NEW PO	05		855				91465 LBS
60600750				30149	MATL REC	05		99				46% BAL
60600750				30149	SN CHG			69		69		62 % UND PO
60600750				31641	SN CHG			325		325		62 % UND PO
60601490				32577	NEW PO	05		2223				252673 LBS
60601490	CM	1200	30		NEW REQT		3215	255			2550	
60602400				31635	SN CHG			314		314		5 % OV PO
60602400				32574	NEW PO	04		439				66335 LBS
60602400	CM	1201			DISB MATL		3195				RUN	NOT FOUND
60603000				33374	NEW PO	04		297				74202 LBS
60603000	CM	1057	9		NEW REQT		3172	99*			2920	
6060****												*ONE ITEM

FIG. 3.
Stock status and daily transactions reports produced by computer give good idea of detailed knowledge of present conditions now avilable to management.

STEEL SUBSTITUTION PROGRAM

When any part is made from a steel size other than the standard steel size called for in the engineering layout, a steel substitution must be made. There are many reasons for substitution, among them:

- Delay of receipt of material on order.
- Small volume of parts, as when the requirements for a short period will be less than a 10-ton minimum steel order and a price penalty will be incurred.
- Unexpected increased customer schedules, with no time to order the standard size steel.
- Excess and obsolete steel due to reduced schedules, cancellations, or model year changes.

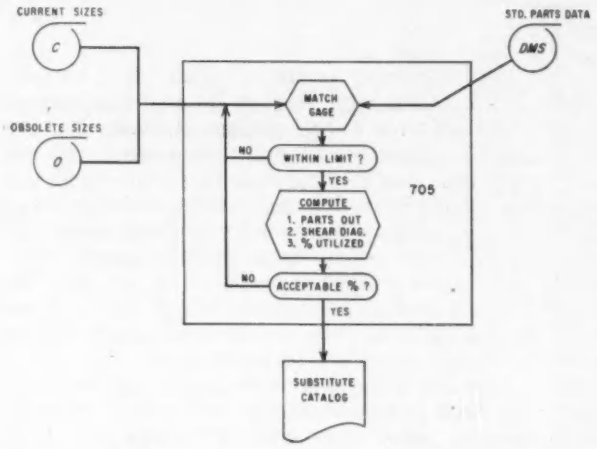

FIG. 4. Program used for computation of substitute steel sizes permits more efficient use of obsolete and excess steel.

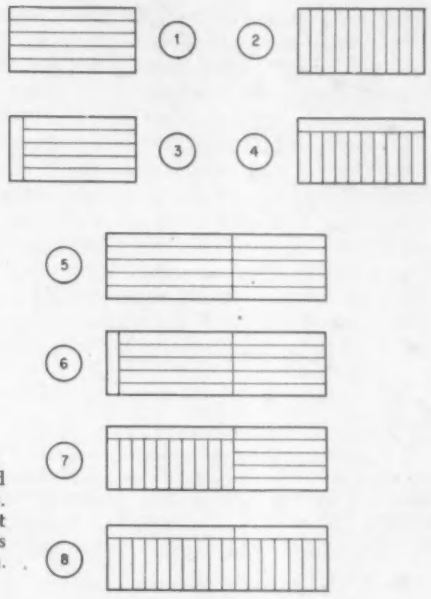

FIG. 5. Steel sheets from sizes in stocks are sheared according to these diagrams to make various parts. Computer calculates percent utilization of sheet to determine which size to use. Only shear diagrams 1, 2, and 5 were ever used with manual computation.

The flow diagram for control of steel substitution is shown in Figure 4. The input data needed is derived mainly from the detail material sheets prepared by the Engineering Control Dept. and from the standard sizes and obsolete steel lists in the stock status tape. Obsolete steel is reduced efficiently.

The 705 was used to prepare a steel substitution catalog which the Steel Procurement Dept. uses to select the best possible substitute size. The catalog was prepared because manual selection and computation is too time consuming and inefficient. For example there might be 75 sizes of 0.119-in. gage steel. Manual computation of the number of cuts and the percent ultilization of all of these sizes for just one part would take at least six hours. The first steel substitution catalog was computed on the 705 in 1958 and had 40,000 possible substitutions with a utilization between 80 and 100 percent. Manually this computation would have required about 40 man-years. On the 705 it now takes 3 hours. From tests, savings from the use of this catalog average $18,000 a year, mainly through the ability of the 705 to compute various shear cuts not commonly sheared.

The 705 can be used to select the best possible way to cut any size sheet for any given part. The basic shear diagrams used are shown in Figure 5. Only shear diagrams 1, 2, and 5 were ever computed manually for a steel substitution. The material savings using the additional 705 shear cuts are far greater than the labor costs for extra handling.

The catalog is presented in two different ways. One is in item number (steel size) sequence which shows what parts can be made from a given size and is useful in disposing of obsolete steel. The second is in part number sequence and will show all the steel sizes that can be used to make a particular part.

IN-PROCESS INVENTORY

The next step beyond the material control program for an integrated production control system is a program to permit the 705 to control in-process inventory, that is, to account for all material, parts, and assemblies from the time the material is disbursed until the final product is shipped. This system is presently in the planning stage. The flow chart in Figure 6 gives an overall picture of the program, which uses the 705 at three stages.

In the first stage, inventory records are updated with the transactions accumulated during the past 24 hours. A shop routing tape serves as the reference file when a part is being fabricated for the first time —the 705 referring to it to obtain the operations to be performed on the part. The inventory tape contains such information as quantity of finished parts available, quantity of parts in various stages of completion (and at what stage they exist), the status of each run number (order number), and the accumulative totals made for the month and for the model year. These records are updated by the various transactions. This first phase produces three tapes: an updated inventory tape complete except for the reduction due to those parts being used in assembly operations, a tape listing all transactions where parts or subassemblies are used, and a tape record of errors which the program is designed to account for.

The second phase takes the list of transactions in-

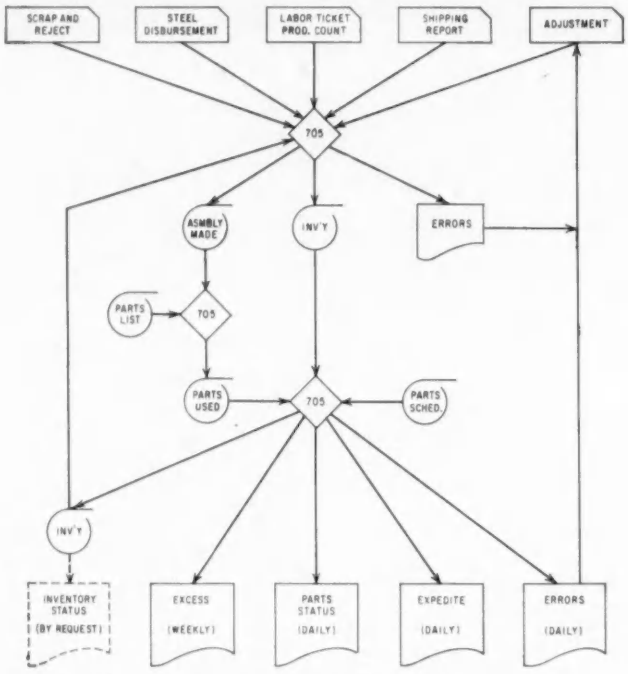

FIG. 6. This program keeps track of material in process of being manufactured, affords schedule planners more time to smooth out load fluctuations and avoid bottlenecks.

volving assemblies where parts are used and, with the parts list tape from the material control program, explodes it into a parts used list in part number sequence.

In the final phase the 705 receives inventory of the components used in the assembly operations and produces an analysis of the present inventory status based on current schedule requirements, that is, an updated and complete inventory tape, a part status report, an expediting report, an error report, and an excess report.

The parts status report can, for every part or assembly, provide number of finished units available, summarize the in-process inventory at specific stages of fabrication, and also indicate requirements by week based on current schedules.

The in-process inventory program will reduce such inventory by relieving shop-schedulers of the task of preparing the parts status report, thus giving them more time to concentrate on the scheduling and reducing lead time between operations.The output of the program will provide data for the next step—automatic scheduling.

MACHINE LOAD FORECASTING PROGRAM

Machine load forecasting is the process of predicting the time required on machines to perform certain scheduled operations; the forecasting procedure is outlined by the flow diagram in Figure 7. The 705 must match a schedule against a parts list to produce a parts requirement list, which is then matched against routing to produce a detailed press load list. The latter list is then matched manually to a press utilization factor list to prepare a summary forecast of the number of shifts required per day on each piece of equipment.

Referring to the flow chart, in the first phase of the program the 705 matches a schedule and a parts list to determine that 5,000 pieces of part 1 and 10,000 pieces of part 2 must be made for 5,000 of assembly A. From the routing tape, two press operations must be performed on part 1, operation 5 on press *a* at 100 pieces per hour and operation 10 on press *b* at 200 pieces per hour. Part 2 has one operation, number 5 on press *a* at 250 pieces per hour. The detailed forecast for each press is therefore computed by dividing the number of pieces needed by the number of pieces processed per hour for each operation.

The essential piece of data for computation of press utilization factors is the labor ticket and is matched against routing (for pieces per hour) to prepare a weekly activity list. The example on the flow chart

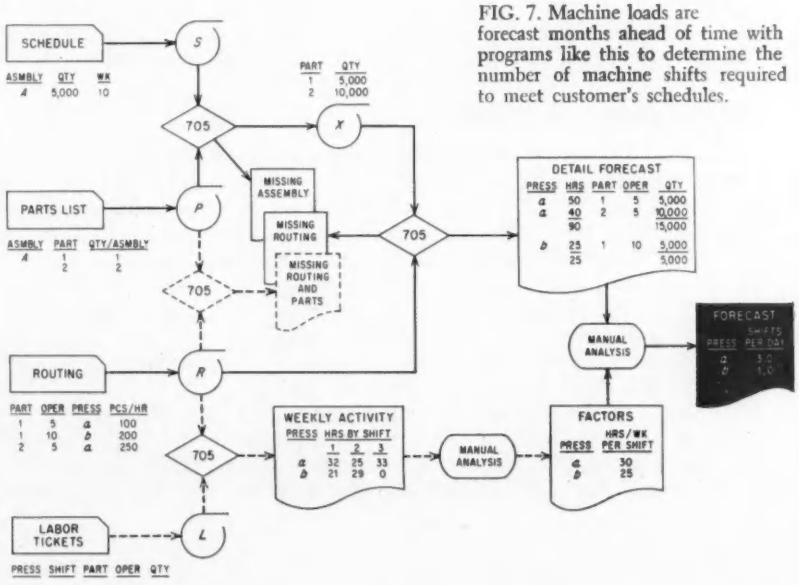

FIG. 7. Machine loads are forecast months ahead of time with programs like this to determine the number of machine shifts required to meet customer's schedules.

shows that press a performed 32 hours of work on the first shift, 25 on the second, and 33 on the third and that b performed 21 hours on the first, 29 on the second, and none on the third shift during a previous week. If this activity is typical of the capacity of these two presses, manual analysis would show a press utilization factor for press a of 30 hours per week per shift and for press b of 25 hours per week per shift. The remainder of the 40 hours available per shift week is accounted for by setup, delays, repairs, inspection, etc. The summary forecast is prepared by applying the factor just calculated to the detailed forecast. Thus 90 hours required of press a during the week being forecast divided by its capacity of 30 hours per week per shift shows that the press must be operated three shifts per day during the forecast week to perform the scheduled operations. Similarly, press b will be required one shift per day.

A long range forecast prepared eight to 10 months prior to the peak of a new automobile year and based upon tentative routing (planning) and preliminary parts lists and schedules permits the spotting of potential overloads while most of the tools are still in the design or early fabrication stage. Short range forecasts of the next three or four months are used to anticipate bottlenecks, smooth load fluctuations, and indicate temporary rerouting as required.

MANPOWER FORECASTING SYSTEM

The 705 has been an extremely powerful management tool for determining a relatively proper and stable manpower utilization in the automotive shop. A somewhat tedious but quite effective manual method had been developed to predict the manpower requirements in the key areas of certain departments. The method paid off because it presented to the shop foremen the peaks and valleys of the anticipated production load in the form of a graph that showed where to reduce labor variations that could easily tie up a schedule to the point of overload and costly overtime production.

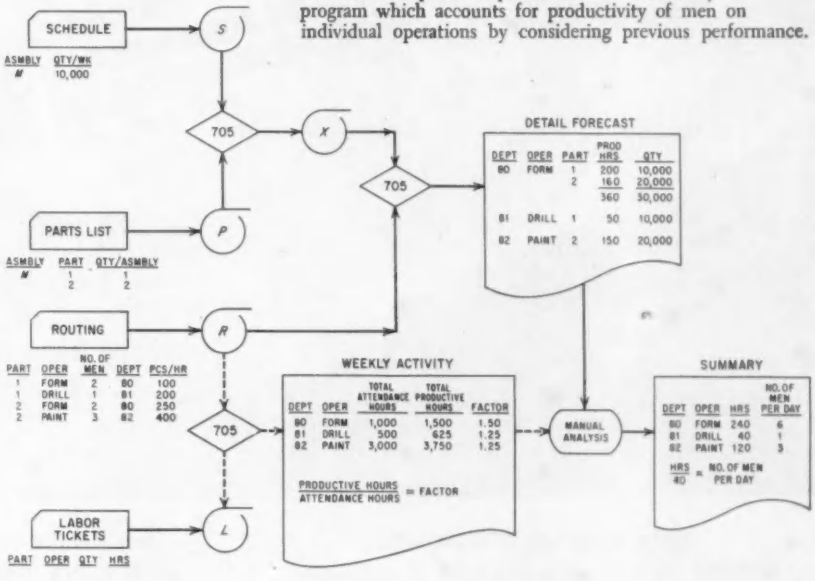

FIG. 8. Manpower requirements are forecast by program which accounts for productivity of men on individual operations by considering previous performance.

The manpower forecasting program developed for the 705 is basically similar to the machine load program just described, as can be seen from the flow chart of Figure 8. Here again the current scheduled requirements are matched against the master parts list and the master routing. But slightly different information is now produced. The routing now tells not only what type of operation is performed on a certain part, but how many men are needed to perform this operation at a specific performance rate.

If 10,000 assemblies type *M* are called for in the schedule and only one part number 1 is required on assembly *M*, the 705 searches the routing tape to find out that two operations, form and drill, must be performed on 10,000 of these parts. If the form operation can be done at 100 pieces per hour, the 10,000 parts can be formed in 100 hours. But this operation takes two men, so the total productive man-hours for this particular job are 200. This is not the complete picture, however. A measure of a man's performance must be included.

The labor ticket provides feedback data on actual production. By accumulating the total attendance hours on a given operation and comparing with the total productive man-hours for the job done during that period (calculating as above), a factor can be derived that is an excellent yardstick to use in determining future productive loads. On the flow chart the factor 1.50 is derived for the forming operation in Department 80 by dividing the calculated man-hours by the attendance hours, that is 1,500/1,000. This factor is then divided into the total forecasted productive man-hours of 360 to find the 240 actual attendance hours needed to form 30,000 pieces of parts 1 and 2 for assembly *M* in a week. Dividing by the 40 hours a week each man can work, six men will be required each day.

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2. OPERATING MODE: Operation controlled by an internally stored program. Single address logic, one instruction per word.

3. PROGRAMMING: Repertoire of 62 instructions. Ease of programming features flexible addressing modes — no address, direct address, indirect address and relative address. Complete programming package includes 22-, 33-, 44-bit fixed point arithmetic, floating point, complex floating point, decimal, floating decimal, and algebraic compiler.

4. INPUT-OUTPUT: Versatile instructions provided to handle available line of input-output devices: 350 character/second paper tape reader, 60 character/second paper tape punch, electric typewriter, up to 8 magnetic tape handlers (either 15KC or 30KC), card reader, card punch, and line printer.

CONTROL DATA CORPORATION

501 PARK AVENUE · MPLS. 15, MINN. · FEderal 9-0411

The Gyroscopic Mass Flowmeter

An old principle—that of the gyroscope—is exploited in a new approach to measuring mass flow. The gyro flowmeter is a loop of pipe vibrating almost imperceptibly that will measure the mass flow of nearly anything passed through it, from heavy liquids to light gases.

MARTIN M. DECKER, The Decker Corp.

The ability to measure true mass flow rather than volume flow is becoming a practical necessity as industry tightens quality control and pricing practices. And certain industries have a natural need for mass flow data—chemical reactions are innately mass reactions.

Principle of the vibrating gyro flowmeter

A mass flowmeter of exceptional accuracy and versatility has been designed based on the gyroscopic principle. If a section of tubing carrying a flowing fluid is bent into a circular loop, the total angular momentum of the fluid in the loop is proportional to the mass flow rate. Gyroscopic action is a response to total angular momentum. Thus, it follows from gyroscopic precession relationships that if a fluid-carrying loop is suspended vertically and vibrated about its vertical diameter (the angular momentum being about an axis normal to the plane of the loop) a precession torque will appear about the horizontal diameter of the loop. It will have the same frequency as the input vibration and an amplitude proportional to the mass flow rate of the fluid in the loop. Such an instrument will measure the mass flow of almost anything passed through it: non-Newtonian fluids, slurries, solids in gases, etc.

Figure 1 shows an early form of the vibrating gyro flowmeter. The center of the loop is the mechanical center of the instrument, which is connected to the external pipeline through two flexible couplings. The fluid makes two right angle bends entering, a 360 deg rotation, and two right angle bends leaving. Since no orifices, vanes, or plugs obstruct the stream, the pressure drop is due only to these bends and the flexible couplings and can normally be made negligible.

The radial pipe sections are freely surrounded by a hollow shaft which forms the horizontal diameter of the loop. The only connection between this shaft and the radial conduits is made at the left end of the horizontal axis where the conduits join the loop. Two reduced sections of the horizontal shaft act as torsion springs to permit the vibration about the horizontal axis.

The vertical shaft is rigidly connected to the horizontal shaft at the center and is bearing-mounted so that the whole instrument assembly can rotate about the vertical axis. A constant speed motor drives the loop through a slot-and-eccentric-pin linkage. The motor can be quite small since only reactive power is required except for the bearing losses. The amplitude of the input oscillation is adjusted by the eccentricity of the driving pin. The frequency is determined by the speed of the exciter motor.

Besides being proportional to mass rate of flow dM/dt, the output amplitude θ is also a function of input amplitude ϕ and frequency ω, both of which must therefore be held constant. That is

$$\theta = \frac{dM}{dt}\left[\frac{2\pi R^2 \phi\,\omega}{k_s\left(1-\frac{\omega^2}{\omega_s{}^2}\right)}\right]e^{j\omega t}$$

in which R is the radius of the loop and k_s is the spring

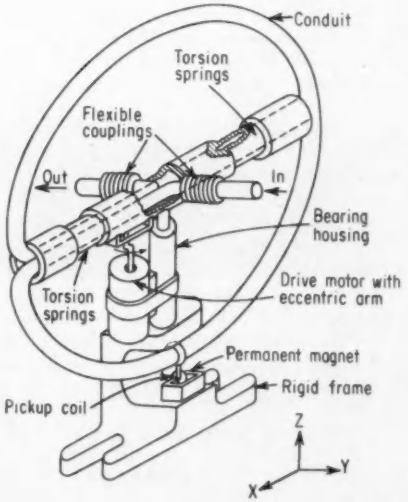


FIG. 1. Early form of gyro flowmeter used to explain basic principle.

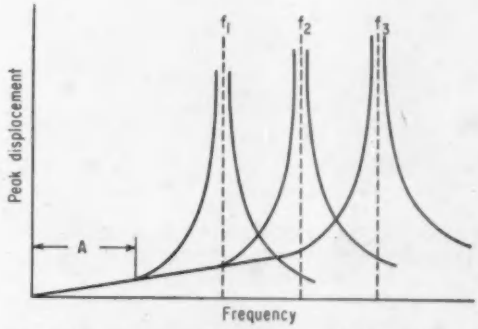


FIG. 2. Resonance between loop inertia and horizontal torsion springs is function of density of fluid in loop; output can vary with density except in low frequency region (A).

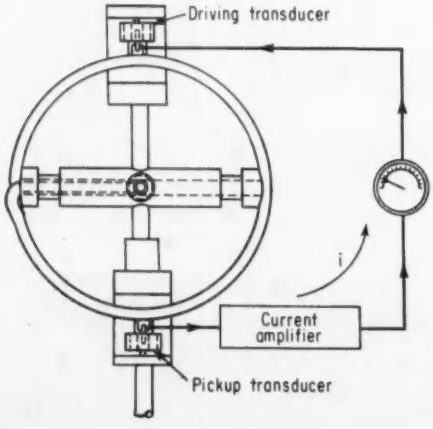
constant about the horizontal axis. Notice that the moment of inertia about the horizontal axis I_x resonates with the spring constant at the frequency $\omega_x = (k_x/I_x)^{1/2}$. Since the moment of inertia of the loop includes the total mass of the fluid in the loop, this resonance frequency depends on the density of the fluid, as shown in Figure 2, in which fluid density is much greater for f_1 than for f_2, etc. Thus, for the instrument to be independent of fluid density the drive must be operated on the low frequency linear portion of the curve at A.

Figure 3 shows a system similar to Figure 1 except for the addition of a torque feedback loop to eliminate the resonance and thus the sensitivity to density. The constant velocity input drive is replaced with a constant torque drive so that in this case, without feedback, the input angle ϕ would vary with frequency, but the torque would be independent of frequency. The voltage generated in a pickup transducer mounted at the bottom of the loop is amplified, and the amplifier output drives a second coil diametrically opposite the pickup. The output is phase-sensitive relative to the input frequency, going through a 180-deg shift at zero mass flow; hence the gyro mass flowmeter will measure reverse flow. Phasing is arranged so the torque produced by the feedback coil opposes the torque due to gyro action of the flowmeter, reducing the amplitude of the output vibration considerably.

The magnitude of the amplifier output current in Figure 3 is directly proportional to mass flow rate. The high negative feedback results in an effectively nonresonant system that permits a high drive frequency and thus a low response time. The constant of proportionality depends only upon basic instrument design parameters and is not affected by age, temperature, pressure, line voltage, viscosity, density, etc. Hence the calibration of the flowmeter is very stable. The current which drives the feedback transducer can be integrated by electrical circuits, watt-hour meters, or many other devices to indicate or record total mass flow.

The prototype meter shown in Figure 4 has been refined mechanically to reduce sensitivity to external accelerations. It has a full scale rating of 500 lb per min using a 1½-in. stainless steel conduit with a loop diam of 12 in. The horizontal resonance frequency is 100 cps and the drive frequency is 12 cps. Drive amplitude is 0.20 deg and the full scale output displacement is 0.0015 deg without torque feedback. An electronic console indicates flow rate and totalized flow rate digitally to better than plus or minus 1 percent of full scale and includes constants for actuating process controllers when total flow or flow rate reach preset values. Telemetering transmitters can be added to transmit data to a remote point.

FIG. 3. Resonance shown in Figure 2 can be damped by negative feedback to driving transducer to permit higher input frequencies and better response to varying mass flow rates.



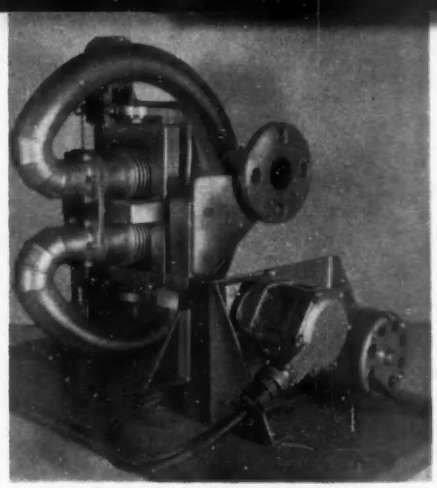


FIG. 4. Prototype meter is mechanically redesigned for low sensitivity to external acceleration.

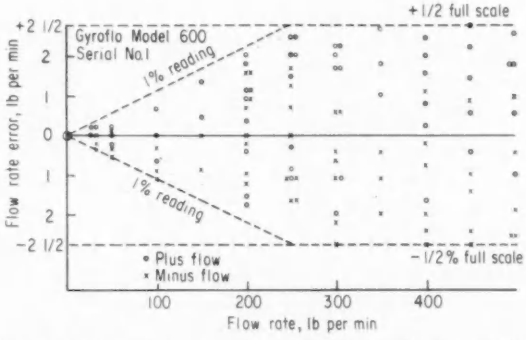
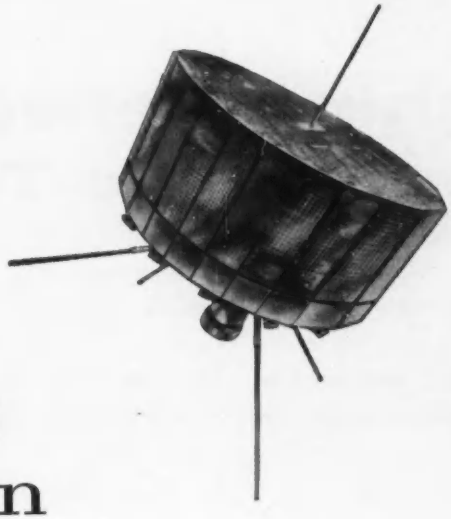


FIG. 5. Prototype shows flow rate error in either direction within ¼ percent of full scale and 1 percent of reading over 20 to 1 range.

Performance of the prototype

In a series of 79 tests performed by Armour Research Foundation, an early crude meter showed an rms error of 0.45 percent of full scale reading. The results of 108 test runs (54 each plus and minus flow) made more recently on the production model by The Decker Corp. are shown in Figure 5. Test flow rates varied from 20 lb per min to 500 lb per min, and all the data fell within plus or minus ½ percent of full scale and plus or minus 1 percent of reading. These test runs were made by weighing the fluid passed through the flowmeter (typically 1,000 to 1,500 lb to plus or minus 2 lb accuracy) and comparing this to the integrated flow indicated by the recorder-integrator unit (Minneapolis-Honeywell Model 153X47VB-II-III-28). The recorder-integrator was calibrated to plus or minus 0.2 percent accuracy.

Improvements suggested by the prototype tests will be incorporated in the first production models which will be 500 lb per min meters priced in the $1,500-$2,500 range. Prices on models to be introduced later with other flow ratings will vary.



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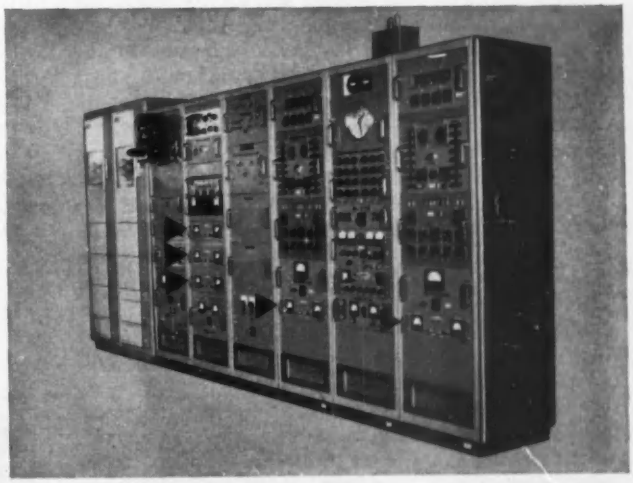

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CIRCLE 141 ON READER SERVICE CARD 141

Switching Networks Program Tube Tester

One second from tube insertion to delivery of punched-card test data is the speed record set by IBM's "STAR". System features large scale logical networks of gold-alloy wire contact relays for establishing circuit parameters and sequencing the test cycle.

PAUL E. HADDON, International Business Machines Corp.

A new quality-control tool, IBM's Special Tube Analyzing Recorder (STAR), tests electron tubes automatically at high speed. The equipment quickly checks sample lots taken from a production run and immediately presents the performance record for each tube in the form of punched cards and a typewritten tabulation. A wide variety of tubes can be handled; programming the tests for any given type requires only a few moments.

The STAR system, Figure 1, consists of an electric typewriter, a console which contains the major logical units, a power supply, and a card punch. A prewired patchboard controls the operation of the basic test circuits and components housed in the console. It does this by selecting the right circuit at the right time and by routing programming pulses that set up the detailed test circuits. The control panel also determines the kind of tests to be done, the conditions of each test (plate voltage, grid resistance, etc.), the sequence of the tests, and the limits against which each measurement is to be compared. Wiring of the patch panel can be done prior to its use in the system. In typical cases 10 or more panels may be wired for the most common tube types. Jacks or hubs on the panel are labeled to indicate the function performed when the hub position is energized.

The STAR performs the static and low frequency dynamic tests listed in the table. The six programmable power supplies are designated as plate, screen grid, control grid, suppressor grid, cathode emission, and filament-heater. Punched and typewritten results are produced in from 1 to 2.5 sec for ac tests, assuming no time delay for stabilization.

Performing the test

Figure 2 is a simplified drawing of the dc static current-measuring circuit. Blocks R_{G1}, R_{G2}, etc. contain a series of resistors having a 1, 2, 3, 6 code relationship, as shown in Figure 3. By energizing the proper relays, any resistance value from zero to maximum can be inserted into the electrode circuit. For example, a value of 940 ohms is obtained by selecting relays 1, 3, 7, and 8. In actual tests the relays are programmed by means of the console plug board to produce the resistance needed to simulate normal tube usage or test conditions.

Tube parameters are found by measuring the voltage across a precision resistor in series with the electrode current. Normally the resistors are valued at 1, 10, 100, etc. ohms and produce a voltage that is direct reading except for the decimal point; thus, no conversion is necessary from the indicated value to the true value. The measuring element is a Non-Linear Systems four-digit digital voltmeter that accepts positive or negative inputs and automatically selects the proper range. The voltage-comparing mechanism in this instrument consists of a series of mercury-wetted contact relays rather than a stepping

TABLE OF PROGRAMMABLE TESTS

Characteristic	Parameter Testing Range
Negative control grid current	0.1–50 μa
Plate current	0.02–300 ma
Screen grid current	0.50 ma
Transconductance (G_m)	500–20,000 micromhos
Ac Amplification	X1–X40
Power output (class A)	1–25 watts
Cathode emission	0.001–1 amp.
Filament current	0.01–3 amp
Minus heater cathode leakage	1 μa–3 ma
Plus heater cathode leakage	1 μa–3 ma
Insulation resistance (one element to all others)	5–500 megohms

FIG. 1. Four units in STAR system are electric typewriter, test console, power supply, and card punch.

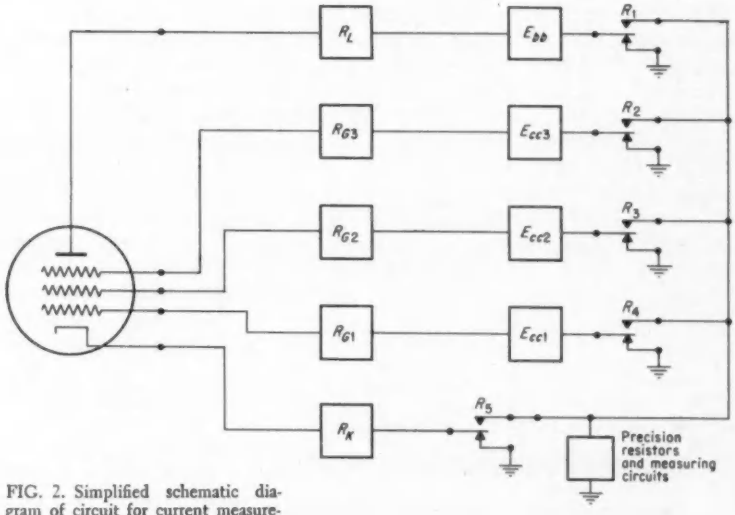


FIG. 2. Simplified schematic diagram of circuit for current measurement. "R" and "E" blocks represent programmable electrode loads and voltages, respectively.

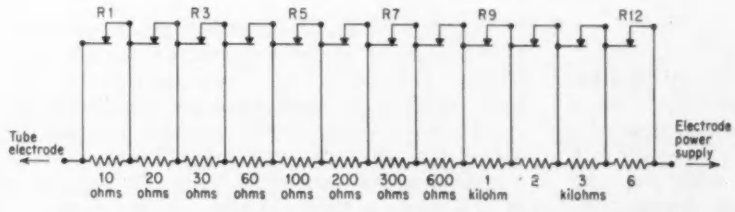


FIG. 3. Coded resistor block can be set for desired resistance by opening proper relay contacts.

switch. The relays are selected in sequence under control of a timing mechanism. As each relay is selected, a comparison is made to determine whether that relay is to be held or dropped. This process continues until all 16 "bit" relays in 2-4-2-1 code have been sampled. The code is converted to decimal digits for visual presentation and readout.

The accuracy of this instrument is 0.01 percent + 1 digit with a resolution of 1 mv. Voltmeter scanning time is approximately 350 millisec. The programmer allows 400 millisec minimum for the complete measurement process. During the voltmeter scan cycle, all programmer functions are interlocked to minimize the generation of noise pulses due to relay current interruptions. The digital reading contained in the voltmeter at the end of scan is that of the current measured.

The digits are then read out serially in 0.1 sec increments to three units: the limit comparator, the card punch, and the typewriter. The limit comparator is a relay network, Figure 4, whose function is to compare the digital reading on the voltmeter against the limits

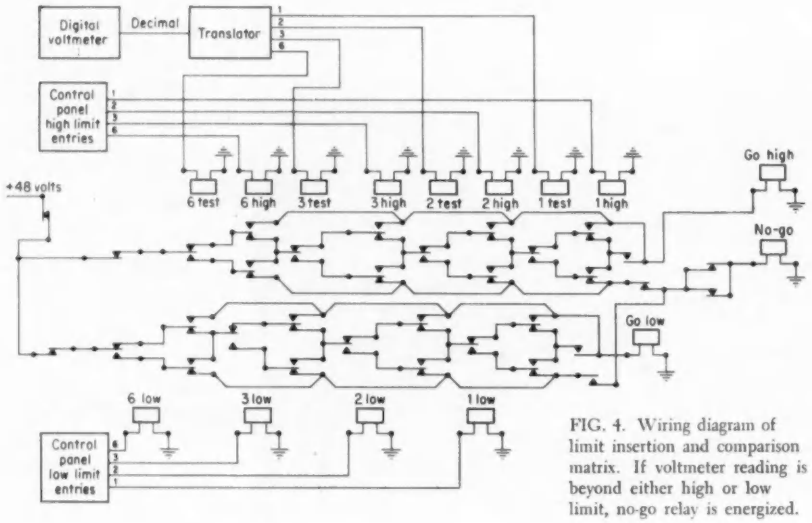


FIG. 4. Wiring diagram of limit insertion and comparison matrix. If voltmeter reading is beyond either high or low limit, no-go relay is energized.

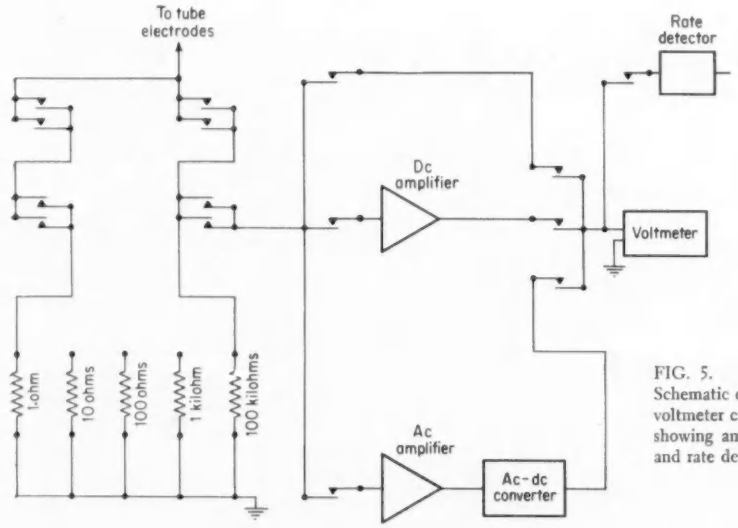


FIG. 5. Schematic of voltmeter circuit showing amplifiers and rate detector.

programmed on the control panel. Coincident with the punching and printing of the fourth voltmeter digit, the relay comparator causes a card "zone punch" to indicate that the test value was either inside or outside of limits.

Dc tests

The tube circuit configuration necessary for a test is set up by selection of a "master" relay, which actuates additional relays in the test and measuring circuit section. There is one "master" relay for each test. This arrangement allows the wires and relay contacts that form part of the test circuit to be physically and electrically isolated from the control circuits. At the start of a typical test, the master relay energizes one of the relays R1 through R5, Figure 2, thus inserting the precision resistors and measuring circuit block in series with the current to be measured. The master relay simultaneously actuates one of the relays seen in Figure 5, which selects the particular electrode circuit that is to be checked. For plate current measurement, for example, R1 is energized so that current flows from the positive terminal of the plate voltage power supply, through the R_L block, and to the tube. The return path is through the R_K block and the ground circuit to the ground connection of the precision resistor and measuring circuit block. Current then flows through the selected resistor (relay contacts are shown for the 1-ohm and 100-kilohm resistors only) and finally to the negative terminal of the plate voltage supply.

All other electrode circuits carry normal currents and may be programmed at will with any values of series resistors. Selection of one of the precision resistors also connects the digital voltmeter across the resistor. If low voltages are to be measured, ac or dc preamplification may be required. The preamplifiers are selected by control panel wiring in the same manner as the precision resistor itself was selected.

Ac tests

Ac tests such as for transconductance, amplification, and power output are performed by automatic selection of additional relays that connect a 1-kc sine wave oscillator in series with the grid circuit for signal input and an ac to dc converter between the output terminal and the digital voltmeter. Transconductance, for example, is found by applying a small ac signal to the grid of the tube and measuring the resulting ac plate current. To satisfy the necessary condition of constant E_b, the plate of the tube

is returned to the $B+$ supply through a 100-henry choke. The ac plate current flows to ground through a low impedance shunt load composed of a capacitor and programmable low resistance resistor. The ac voltage across the resistor is amplified, converted to direct current, and measured by the digital voltmeter. The magnitude of signal input is selected by picking relays that tap a precision resistor connected across the oscillator output.

Power output tests employ about the same circuit configuration as transconductance but usually require loads of several thousand ohms. These are furnished by a coded series of resistors that are relay-selected to cover the range from 0 to 15,000 ohms in 100 ohm steps. The voltage across the load resistor is fed to a vacuum tube voltmeter, which incorporates a diode ladder squaring circuit to provide an indication equal to the true rms input voltage.

Some tube currents do not reach a steady value immediately after the external circuit is completed but rise over a period of tenths of seconds or more. To ensure that the current being measured is of constant amplitude, the STAR employs a rate detector which consists of an *RC* differentiator, chopper amplifier, and rectifier. The detector is connected in parallel with the digital voltmeter input terminals. When the voltage input is constant, the differentiator output is zero. When the input voltage is changing, however, the differentiator delivers a voltage output to the chopper, which in turn produces a low voltage square wave. This is amplified, rectified, and used to pick up a relay that interlocks the voltmeter. The voltmeter cannot start its scan cycle until this relay is in its normal (unenergized) condition. Because some tube types oscillate slowly about a dc value for long periods of time, the rate detector may remain energized and prevent continuation of the test sequence. A delay timer restarts the test sequence if stabilization is not achieved within an arbitrary period. When this occurs, the card is punched to indicate that the tube was not stable during measurement.

Reliability and noise

The relays chosen for STAR's large scale logical switching capability are plug-in wire contact units with gold-alloy wires and contacts. These relays have high mechanical and electrical reliability, and produce negligible effects on the circuit in which they appear. The latter is important because the measuring circuits pass low level currents and voltages; hence the switching contacts must not introduce intolerable voltage drops or rises. The gold-alloy contacts have resistances ranging between 5 and 50 milliohms, are not attacked by normal atmospheric environments, and can reliably switch "dry circuits" for tens of millions of operations. Minimum voltage drop across relay contacts is further insured by paralleling contacts as shown in Figure 5.

The wire contact relays are not restricted to vertical mounting as are mercury wetted contact relays. The contacts are supported by a molding of glass-filled alkyd resin, which has a resistance several orders of magnitude greater than normal black phenolic plastics and does not readily absorb moisture. This combination of characteristics minimizes shunt conductances and therefore reduces ohmic coupling between high voltage circuits (such as those at plate voltage level) and low level circuits.

Programming mechanisms and control circuits are the source of noise voltages not found in manually operated test devices. These noise voltages include: inductive surges from relay and circuit actuation, hum voltages from ac power lines, and

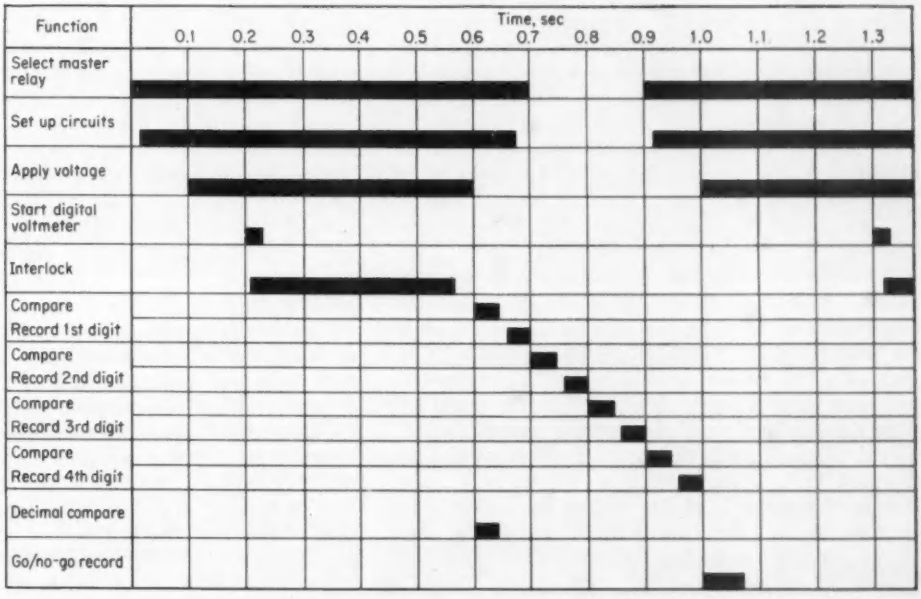


FIG. 6. Timing diagram for test sequence.

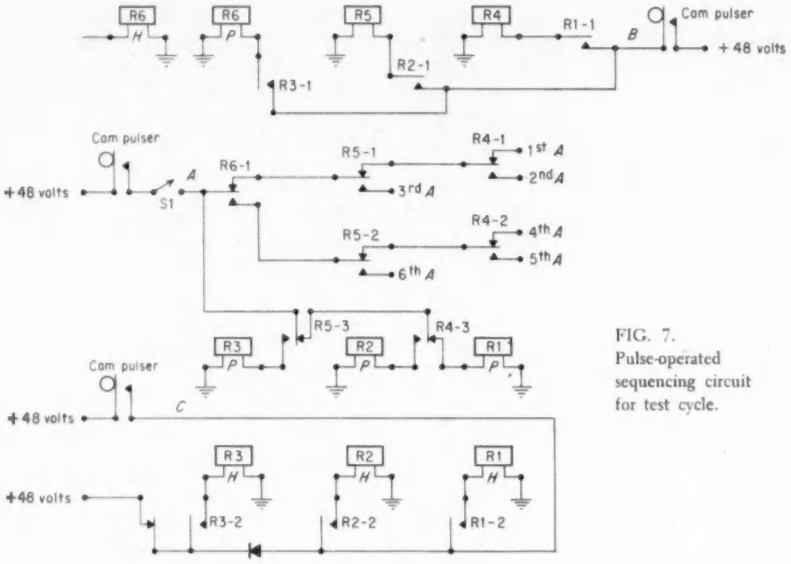


FIG. 7. Pulse-operated sequencing circuit for test cycle.

dc "cross talk" from shunt conductances. The noise frequencies vary from dc to several kilocycles and completely blanket the frequency range in which measurements are to be made. This fact rules out filtering to improve signal to noise ratios. Consequently, noise must be eliminated at the source.

The effect of relay and circuit breaker noises is reduced by interlocking the system programmer during measurement. The system timing cycle provides a 0.4-sec "dead space" in the middle of the test cycle during which a minimum number of relays are actuated. Those units that must function during the "dead space" are connected to suppression networks composed of diodes or series resistor-capacitor networks. Diodes connected in shunt with a relay hold coil, for example, reduce the inductive voltage "kick" caused by interrupting the hold circuit current from 100 volts to a few volts or less. Unless suppressed, inductively produced voltages of this magnitude may cause voltage spikes of up to a few volts in the measuring circuits.

Noise from 60-cycle power lines is minimized by shielding and locating the lines as far as possible from the measuring circuits. Alkyd resin moldings in the relays and Teflon insulated wire in measuring circuits lines effectively eliminate dc crosstalk.

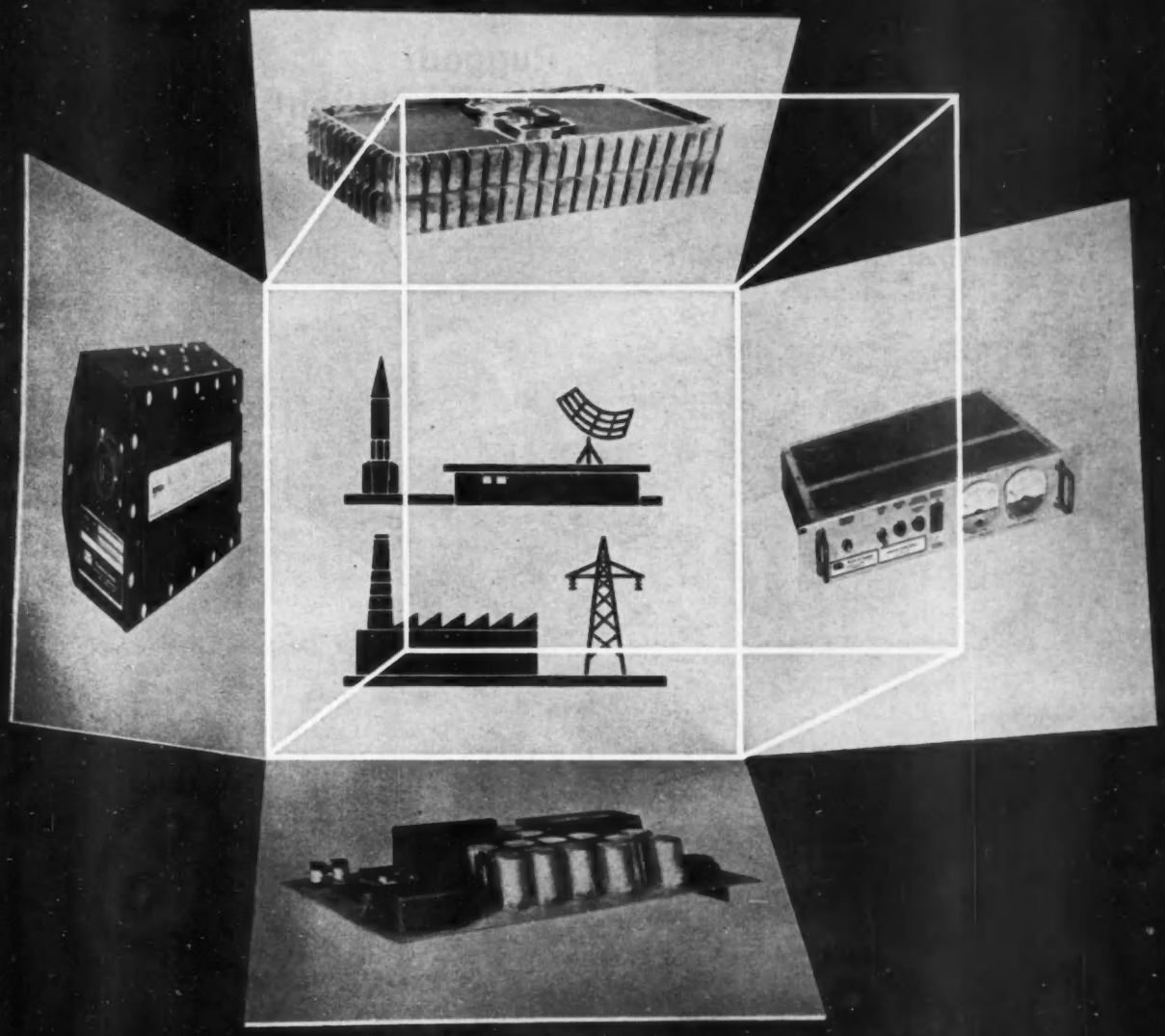
All relays are mounted on swing-out gates for easy access. Measuring circuit relays are on a gate located close to the tube test sockets; the relays used for programming and test stepping are located further away for circuit isolation. The measuring-circuit gate area is completely enclosed in metal to reduce capacitively and inductively coupled noise. Signal wires entering the box are either coaxial or shielded cable. The measuring circuit relay gate contains all relays used for setting up circuit connections to the tube under test, as well as the connections to the amplifier, voltmeter, and precision resistor measuring circuits. For minimum lead lengths, the precision resistors are mounted directly on the bases of the relays used to switch them into the circuit.

Sequencing

Once programmed for a given tube type by means of the patchboard, the STAR system performs repetitive test cycles automatically. Each cycle starts when a tube is manually inserted into a test circuit and consists of the timed steps shown in Figure 6. It is controlled by means of a pulse operated sequencing circuit. Pulses are generated by three cam-actuated circuit breakers feeding the relay counter configuration shown in simplified form in Figure 7. The *A*, *B*, and *C* cams cause 48 volts to appear cyclically on the *A*, *B*, and *C* pulse lines in the proper time sequence needed to energize the relays R_1, R_2, etc. that control the various operations listed in Figure 6. Relays R_1, R_2, R_3, and R_6 are magnetically latched; a main operating coil is designated as *P* (for "pick") and a latching coil as *H* (for "hold"). *A*, *B*, and *C* pulses occur 10 per sec; six *A*, *B*, and *C* pulses are required for one test cycle.

The first *A* pulse occurring after the switch S_1 closes energizes relay R_1 through coil 1*P* and contacts *R*5-3 and *R*4-3. Relay R1 is latched through hold coil *R*1-*H* and relay point R1-2 until the end of the first *C* pulse. The first *A* pulse also appears at the output hub labeled "1st *A*". The *B* pulse occurring after the first *A* pulse energizes *R*4 through contacts *R*1-1, enabling the second *A* pulse to pick *R*2 through coil *R*2*P*. Relay R2 is held until the end of the second *C* pulse. The second *A* pulse also appears at the output hub labeled "2nd *A*". The second *B* pulse picks relay *R*5 through contacts *R*2-1. This action allows the third *A* pulse to pick *R*3 through its pick coil *R*2-*P*. This type of sequence continues until six *A* pulses have been generated to complete one test cycle. The pulse after the sixth *A* pulse is the first *A* pulse of the next test cycle.

The test cycle may be interrupted at any time by opening switch S_1. As soon as S_1 closes again, the test cycle will continue from the exact point of stopping. This feature is used to shut down the sequencing circuits momentarily to allow the tube currents to stabilize and the digital voltmeter to make a complete scan. During a test a second tube may be inserted in the second socket. After completion of the tests, the first tube is removed and testing of the second tube begins automatically.



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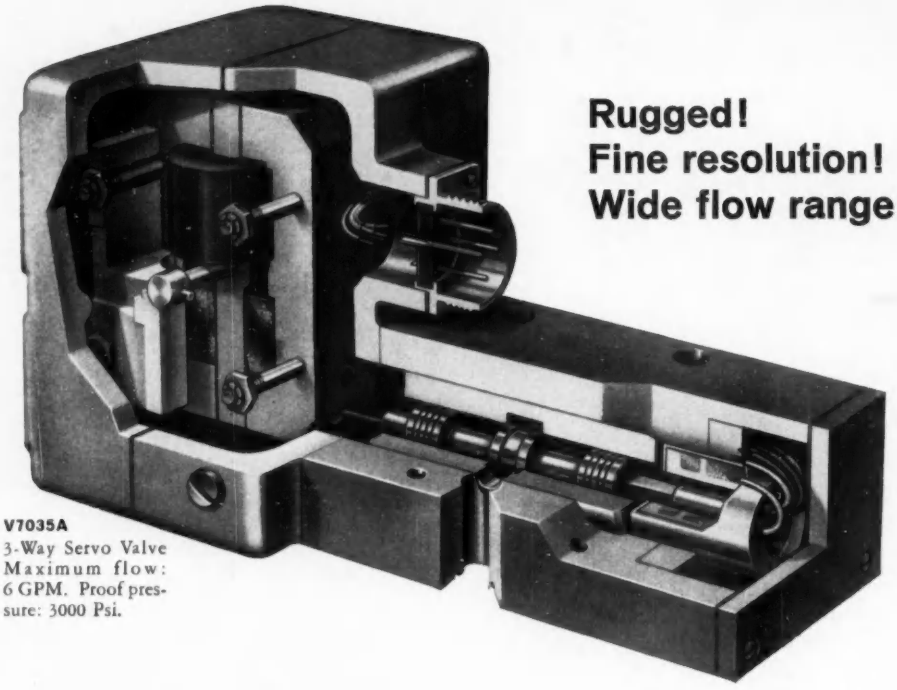

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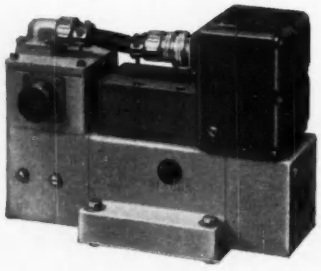

V7040A
2-Stage Servo Valve
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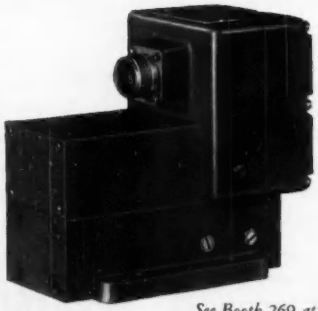

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Binary Pneumatic Cylinders Position Printer Head

ROBERT M. ROSE
Potter Instrument Co., Inc.

The unique pneumatic positioning device pictured in Figure 1 and diagrammed in Figure 2 was designed to locate a mechanical printing head over any of 96 paper strips that represent aircraft within the jurisdiction of a flight control center. These strips are arranged in 24 groups of four, vertically over a 32-in. span. The positioner must center the printing head on each strip within plus or minus 0.020 in.

The pneumatic cylinders act via rollers to change the effective length of a chain fastened at one end to the print head carriage (protruding to the left near the bottom of Figure 1) and at the other end to the piston rod of cylinder 1. Thus each cylinder shortens the external length of chain to which the print head is attached by twice the length of its stroke, except for cylinder 1 which moves the print head by the amount of its stroke only. The routing of the chain and the numbering and stroke of each cylinder are indicated on Figure 2.

The pneumatic cylinders are used as binary devices; that is, the pistons may be in either of two positions only when printing occurs: fully extended or fully withdrawn. An inactive cylinder is fully extended and vice versa. The vertical format required for the air traffic control board is shown in Figure 3. The bottom lines of the individual groups are spaced at equal intervals of 1.150 in. The stroke lengths of cylinders 4 through 8 are arranged to move the printer head in binary increments of 1.150 in.; that is, cylinder 4 represents the binary units position, cylinder 5 the 2's, cylinder 6 the 4's, etc., as:

Cylinder	8	7	6	5	4
Group					
1	0	0	0	0	1
2	0	0	0	1	0
3	0	0	0	1	1
–	–	–	–	–	–
23	1	0	1	1	1
24	1	1	0	0	0

so that the bottom line of group 1 can be reached by actuating cylinder 4 and the bottom line of group 23 by actuating cylinders 8, 6, 5, and 4. The three additional lines in each group are reached by adding ¼, ½, or ¾ in. increments by actuating cylinders 1, 2, or 1 and 2 respectively (Figure 3). Cyl-

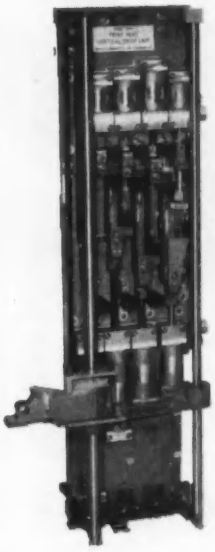
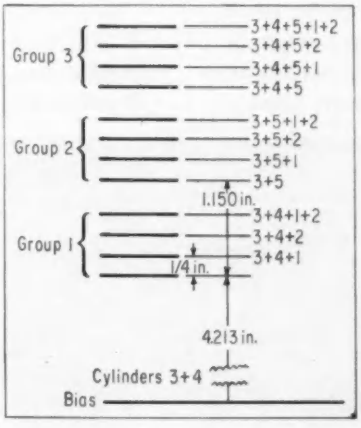


FIG. 1. Binary coded pneumatic positioner for print head on air traffic control board.

FIG. 3. ATC board format. Bottom lines of various groups are reached by selecting proper combinations of cylinders 4 through 8, lines within groups by combinations of cylinders 1 and 2. Print head is biased off board at bottom when not in use; bias is removed by cylinder 3.



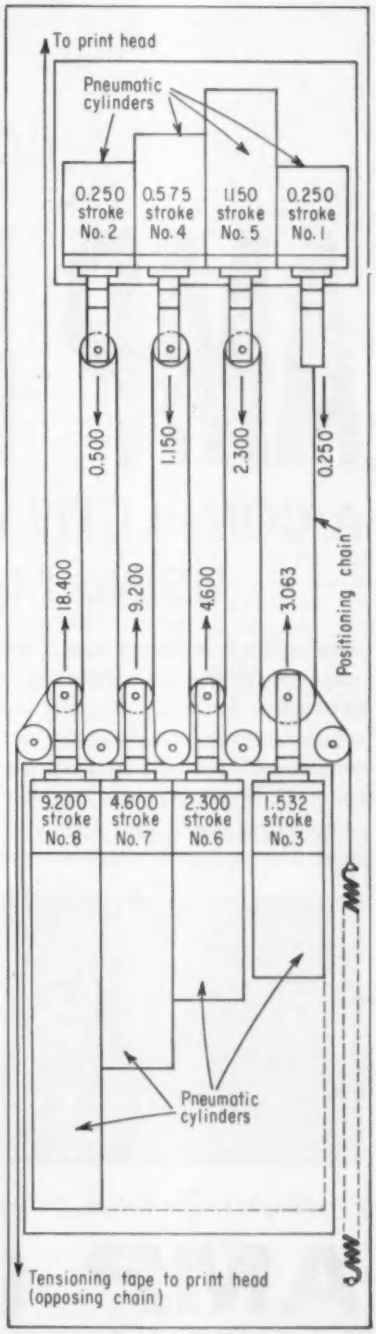
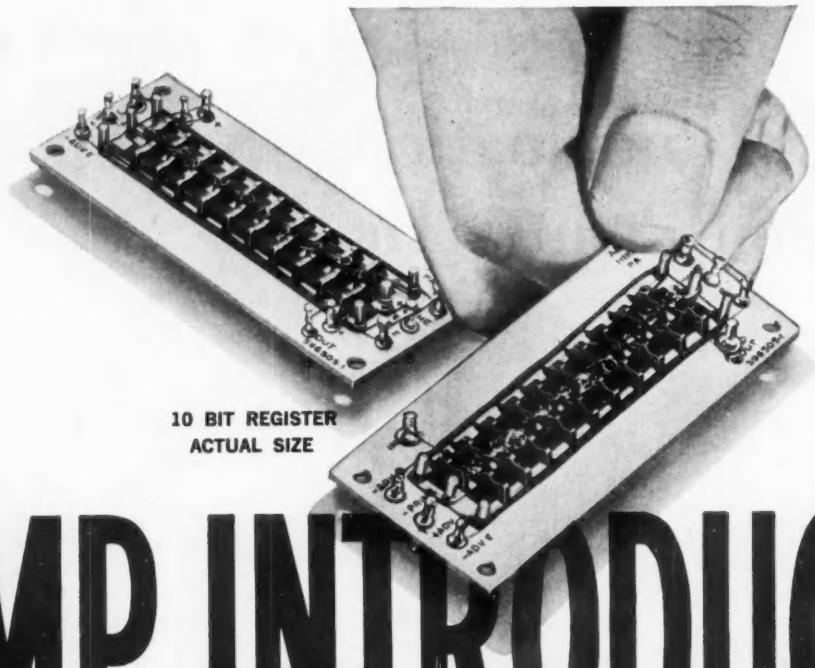


FIG. 2. Length of chain attached to print head is shortened in binary increments.



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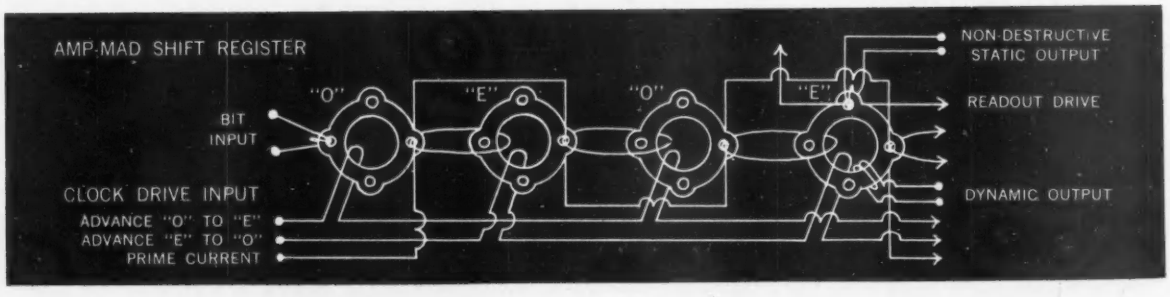

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inder 3 removes a bias that places the print head completely off the board at the bottom when it is not in use, and so it must be actuated whenever the printer is used.

The speed of the print head is controlled by orifices in the intake and exhaust lines of each cylinder. These orifices also make the speed of operation insensitive to line pressure fluctuations. The print head is positioned line to line in 2 sec and will traverse the full 32-in. span in 7 sec. The unit requires 1.5 cfm of air at 100 psig. A spring loaded tensioning tape is wrapped over additional rollers on the lower pistons (Figure 2) to provide additional return force for the cylinders and to keep all slack out of the chain.

A large knurled nut at the end of the piston of cylinder 1 permits accurate "zero adjust" of the print head on the board and makes it easy to correct for this kind of change in case the chain lengthens due to wear. The span will not change due to wear in the chain. The entire positioner has been designed for a minimum of 20 million operations.

Colorimeter Prevents Mixing of Transformer Insulating Liquids

J. P. KINNEY and J. W. BURNETT, General Electric Co.

The liquid dielectrics used as coolants in transformers are highly refined to meet the requirements of the manufacturers and of Underwriters' Laboratories. Generally they fall into two categories—oils and askarels. General Electric Co., for example, uses both fluids, trade-marked 10-C and Pyranol liquid dielectric, respectively. The oil is mineral hydrocarbon; Pyranol is a chlorinated liquid.

In case final assembly tests on the transformer and its liquid fail to meet the narrow specification margins, the liquid is drained and replaced. But even with separate tanks for storing the out-of-spec fluids before reclaiming, the draining process allows the possibility of mixing the two types. Pyranol will attack some of the insulations used in transformers designed for 10-C oil, and the oil will limit the nonflammable properties of the Pyranol. Since the fluids are mutually soluble, separation is not practical and any mixed liquid must be discarded.

A difference in color, however, permits immediate detection of any mixing. A light transmission curve for 10-C oil shows maximum absorption at 390 millimicrons, at which wavelength Pyranol exhibits only slight absorption. Thus if a measured amount of light at 390 mμ was passing through Pyranol insulating liquid and there was 10-C oil present, the light transmission would not be normal.

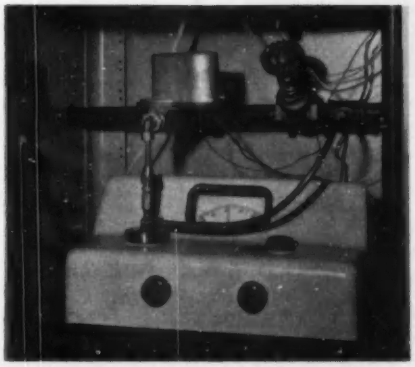
The light transmission characteristics of the liquids are measured in the laboratory with colorimeters which consist basically of a source of light, some means of selecting a certain wavelength of light (such as a prism or filter), a sample container through which the light is passed, and a photoelectric cell to determine the amount of light passing through the sample.

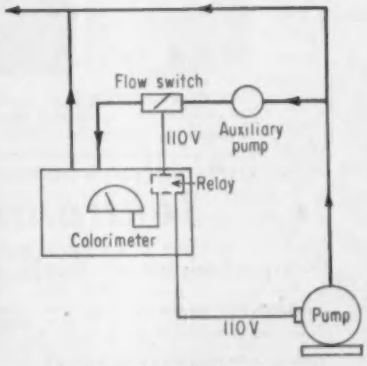
The sample cell compartment of a Bausch & Lomb Spectronic 20 colorimeter was replaced with a pipeline adapter. Since this instrument is installed in the bypass of the pipeline, it was also necessary to install a flow switch to insure continuous flow. The transformer drainage outlets are connected to a line (either the 10-C line or the Pyranol line) leading to the pump and then to the storage tanks. The bypass is the gate to the monitoring system: a portion of the draining liquid is pumped from the main line through the auxiliary pump, the flow switch, and into the colorimeter which continuously tests the liquid.

In the case of Pyranol the output meter of the colorimeter is set at 100 percent light transmission. If 10-C oil enters the light path, the percent transmission is greatly reduced. To detect this drop in transmission, a relay meter was installed in series with the output meter of the colorimeter. This meter makes contact at 100 percent transmission, and a drop in transmission deenergizes the pump contactor to prevent contaminating the Pyranol storage.

When monitoring 10-C oil the output of the colorimeter is set at 25 percent light transmission. If Pyranol enters the light path, the transmission increases. Thus, it was necessary to use a relay meter with both lower and upper contacts to make the instrument fail-safe. These contacts are set at 15 and 35 percent transmission, respectively. Either a drop in transmission due to instrument failure or an increase in transmission due to presence of Pyranol deenergizes the pump contactor.

In trial runs with known small amounts of contamination, the mixture was detected immediately with this system. Since the time of installation there has been little recurrence of inadvertent mixing, very likely due to the psychological effect of an automatic quality control "watch-dog" on operator efficiency.





Colorimeter monitor is installed in bypass on line to storage tanks for insulating liquids.

2 NEW

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TYPE 503

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dc to 450 kc

VERTICAL AND HORIZONTAL AMPLIFIERS
Differential input at all attenuator settings.
1 mv/cm to 20 v/cm in 14 calibrated steps.
Continuously variable between steps, and to approximately 50 v/cm uncalibrated.
Constant input impedance at all sensitivities (standard 10X probes can be used).

SWEEP RANGE
1 μsec/cm to 5 sec/cm in 21 calibrated steps.
Sweep time adjustable between steps, and to approximately 12 sec/cm uncalibrated.

SWEEP MAGNIFICATION
X2, X5, X10, X20, and X50 Magnification.

AMPLITUDE CALIBRATOR
500 mv and 5 mv peak-to-peak square-wave voltages are available from front panel.

3-KV ACCELERATING POTENTIAL
5-inch Tektronix crt provides bright trace, 8-cm by 10-cm viewing area.

EASY TRIGGERING
Fully automatic, amplitude-level selection on rising or falling slope of signal, or free-run (recurrent). AC or DC coupling, internal, external, or line.

REGULATED POWER SUPPLIES
All critical dc voltages electronically-regulated, plus regulated heater supplies for the input stages of both amplifiers.

SIZE AND WEIGHT
13½" h, 9¾" w, 21½" d—approximately 29 lbs.

TYPE 504

The Type 504 has the basic features desirable for most general-purpose applications — sensitive vertical amplifier, linear sweeps, easy triggering, amplitude calibrator.

FREQUENCY RESPONSE
dc to 450 kc

VERTICAL AMPLIFIER
5 mv/cm to 20 v/cm in 12 calibrated steps.
Continuously variable between steps, and to approximately 50 v/cm uncalibrated.
Constant input impedance at all sensitivities (standard 10X probe can be used).

SWEEP RANGE
1 μsec/cm to 0.5 sec/cm in 18 calibrated steps.
Sweep time adjustable between steps, and to approximately 1.2 sec/cm uncalibrated.

AMPLITUDE CALIBRATOR
500 mv and 25 mv peak-to-peak square-wave voltages are available from front panel.

HORIZONTAL INPUT
0.5 v/cm, with variable attenuator.

3-KV ACCELERATING POTENTIAL
5-inch Tektronix crt provides bright trace, 8-cm by 10-cm viewing area.

EASY TRIGGERING
Fully automatic, amplitude-level selection on rising or falling slope of signal, or free-run (recurrent). AC or DC coupling, internal, external, or line.

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Simple Logic Logs Lab Measurements

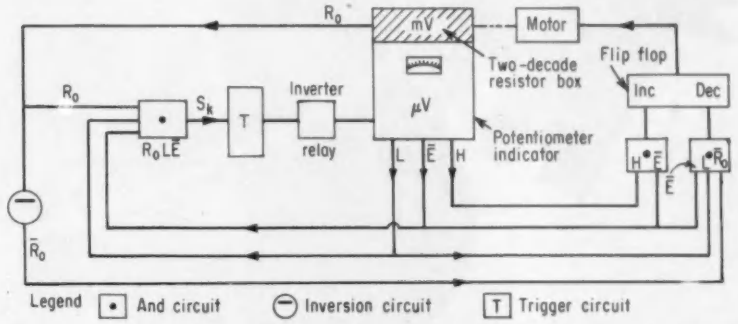
JACQUES VIDAL
University of Liege, Belgium

Typical testing programs at the Thermodynamics Laboratory of Liege University call for recording of up to 576 thermocouple, flux, and flowmeter readings at the rate of 1,200-1,800 per hr. Simple logic circuits coupled to a standard indicating potentiometer and stepping switch scanners eliminate all manual recording and provide a complete data printout for a nearby computer center.

Much of the laboratory's work is evaluation for industry of thermal characteristics of radiators, heating panels, air conditioning units, curtain walls, structures, and building materials. Practical evaluation calls for multipoint recording of the air temperatures and flows set up around the body which is placed in a specially constructed test cell with calorimetric walls. Internal surface temperatures in the 20 x 14 x 14-ft cell are controlled in sections by circulating water through built-in aluminum radiating panels. Simulation of different external conditions such as rain and snow is either by adjusting inner surface temperatures, or by replacing one of the cell walls with a real wall against which the conditions are simulated. In changing over to automatic logging from former manual recording of each test point, budget limitations demanded the maximum use of already installed equipment such as multiposition thermocouple switches and Honeywell self-balancing microvolt potentiometer indicators.

To use the Honeywell indicator with its unidirectional 0-1,100 microvolt input for automatic measurements, modifications in the form of simple logic circuits were added to provide automatic range changing on higher input voltages and polarity inversion to handle the bidirectional inputs from flowmeters.

Automatic range extension up to 60 millivolts is obtained by a servo driving the two-decade precision resistance box provided with the indicator. Position contacts on the resistor box switches stop the servo only when switches are correctly located in one of their 10 discrete positions. An additional contact R_o closes when the switches are at their zero position. Two sets of conditions govern the servo's rotational direction. For increasing range the servo must detect when the indicator is off scale at the top end of its dial, while off scale at the bottom end must reduce range. The second condition permits range changing only when an unbalance exists in the self-balancing indicator, ensuring that signals just within the top and bottom limits of the indicator do not trigger the range servo.



AND circuits and trigger units provide automatic range changing and polarity inversion for standard microvolt indicator. Inverter circuit operating on R_o signal (zero decade switch position) locks out servo on negative input signals.

Two contacts L and H are fitted to the indicator dial itself, L being energized at the zero and H at the 999-microvolt position. Unbalance detection is from additional relay circuits in the indicator providing a binary signal E at balance or $\bar{E}$ when out of balance. The diagram shows the logic schematic. Two AND circuits control a flip-flop governing the servomotor direction. Range is increased only when inputs $H \cdot \bar{E}$ are present. Input $\bar{R}_o \cdot L \cdot \bar{E}$ to the second AND circuit reverses the motor direction; absence of R_o signal when decade switches are at zero locks out range reduction.

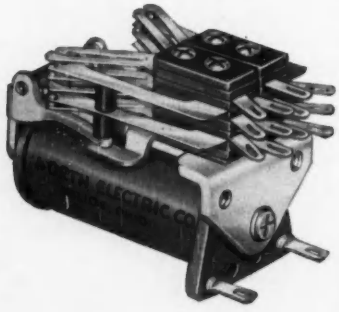
Polarity changing of the indicator input to accommodate negative inputs from the flowmeter signals also uses the R_o contacts on the decade box. Generation of signals $R_o \cdot L \cdot E$ signifies the presence of a negative voltage, as unbalance still occurs when the indicator pointer is at its zero position. These three inputs feed a third AND unit to operate a trigger circuit. Each successive input to the trigger actuates a special inverting relay reversing the indicator input connections to handle incoming negative emf's.

To incorporate previously installed 25-position thermocouple selector switches in the new logging installation, stepping motors fitted to the switch shafts provide sequential scanning of each position. The 576 test points are routed in groups of 24 to 24 selector switches, each group being selected by a 25-position group selector stepping switch. Twenty-fifth position on both group and group selector switches maintains correct synchronization between the switches and memory circuits generating the test point addresses. To speed up the test sequence, jumper links allow unused test points to be omitted.

Connection of a new test point to the indicator unbalances the potentiometer circuit, and the unbalance voltage $\bar{E}$ inhibits all logging operations until equilibrium is restored. Restoral to E at balance operates a one-shot trigger circuit that restores anode voltage to a thyratron decoding matrix and starts the print out of address and measurement.

Besides local print out at the test center and an in-line indication of the address being scanned, the coded information is fed direct via a 300-yard 24-pair cable to a tape perforator at the university's Computation Center. The tape is read by the center's IBM 650, programmed to group all measurements belonging to the same address and then to calculate their mean value, eliminating all points outside a certain statistical scatter.

are you using North Electric's Workhorse "E" relay?



Expanded production facilities and increased efficiency in manufacturing methods have enabled North Electric to step up production of "E" relays to provide prompt delivery (at a new low cost, too) to an ever-growing list of steady customers.

If you need a relay that incorporates the inherent proven dependability of a telephone-type relay with minimal spatial requirements, this "little workhorse" from North can be your answer!

GENERAL CHARACTERISTICS:

Light Weight (2½ ozs.)
Compact (Length 2¼"; Width 1⅛"; Height 1¾" max. with 10 springs in either pile-up)
Long Life (over 100 million operations)

SPECIFICATIONS:

Coil Voltages: Up to 250V DC
Contacts: Independent action twin contact springs
Contact Materials: Palladium, Gold, Platinum
Forms: A to C
Speed: 3 ms. minimum
Residual: Lock Screw (adjustable)—Fixed (nylon flap type)
Time Delay: Available for both operate and release
Coil: Single or Double wound
Mountings: 2 #6-32 Screws on ¾" spacing
Accessories: Dust Cover and Hold Down Bracket

ELECTRONETICS DIVISION

NORTH ELECTRIC COMPANY

615 S. Market St., Galion, Ohio

Digital Servo for Numerical Control Uses Unique Transducer

The Bendix machine control unit receives complex information concerning the machining of a part as data on a punched plastic tape. Its output is a series of pulses representing incremental changes of position to be made on each of the three axes of the machine tool. Figure 1 is a simplified schematic of the "digital" servosystem used on each machine axis, with the pulse train output from the machine control unit as the input. In this pulse train each pulse represents a 0.002-in. plus or minus change in X-axis position. The axis feed rate is determined by the rate at which these pulses appear from the control unit and range from zero up to 240 in. per min, or 20,000 pulses per sec.

Notice that a digital feedback signal from a digitizer geared to the X-axis lead screw is compared with the command signal from the control unit output mixer in an error register to generate an input signal for the analog hydraulic servo which drives the lead screw. This digitizer is an electromagnetic transducer (case 2.8 in. diam by 2.5 in.) that uses no brushes, slip rings, or commutators.

Two discs with printed wiring form a variable transformer, with the secondary of the transformer on the stator, Figure 2. The printed wiring on both the rotor and the stator has a square waveform (shown straightened out). The rotor pattern is excited from a 1.6-Mc source, and the stator pattern is energized inductively from the rotor across a few thousandths of an inch gap. The output from the stator depends on the coupling that exists between the two patterns due to their relative positions. When the pattern on the rotor lines up exactly with that on the stator (position 1, Figure 2), maximum coupling exists and the output will be maximum. When the rotor position shifts 90 deg to position 2, the vertical lines of the stator pattern will lie between vertical exciting lines of the rotor pattern of opposite current flow, hence output approaches zero. In position 3, output is again maximum but 180 deg out of phase with the reference.

The printed patterns in the transducer will produce 1,000 full cycles of

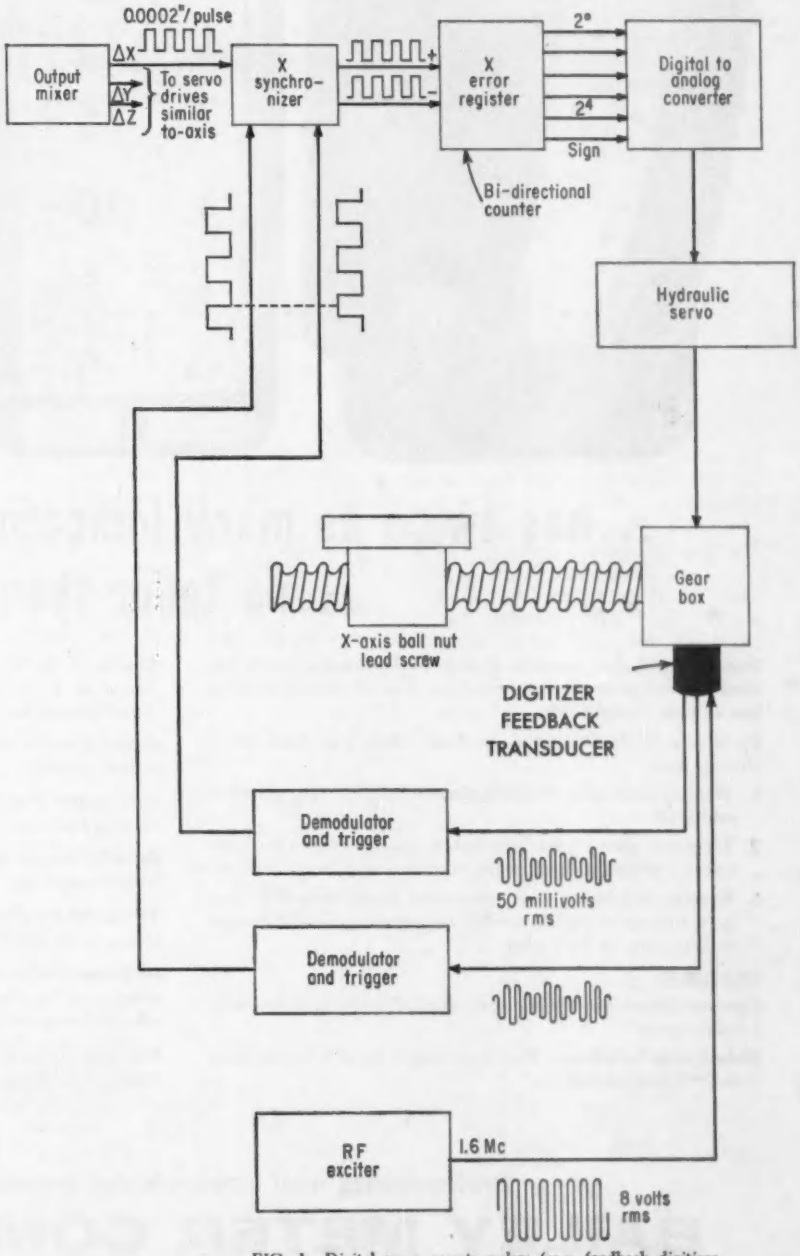


FIG. 1. Digital servo counts pulses from feedback digitizer with command pulses in a bidirectional counter (error register). Binary resistor network is then used to convert error to analog signal for input to electrohydraulic servo.

NEW BAILEY
Multi-Pointer Gage

...has twice as many indicators
...no taller than a telephone!

Now the popular versatile Bailey Multi-Pointer Gage has been reduced in size to conserve control panel space—without loss of easy *readability*.

Each new Multi-Pointer Gage Unit offers you these three choices to—

1. Measure and indicate draft, pressure, differential pressure and level.
2. Transmit above variables either pneumatically or electrically to remote indicators, recorders and/or controllers.
3. Receive and indicate any measured variables which may be transmitted pneumatically by standard SAMA ranges of 3-15 psig. or 3-27 psig.

FEATURES

Compact Size—Two large, easily-read 7″ scales in space only 4 inches wide.

Wide Range Selection—Standard ranges from 0-0.5 in. H_2O to 0-5000 psig available.

Choice of Standard Colors—Satin Black, Slate Gray, Moss Green, or Terra Tan may be selected as an exterior color at no additional cost.

Colored Scales—Scales available in white, red, green, blue, yellow, or orange.

Fluorescent Illumination—All gages have slideout unit containing bulb and starter for ease of maintenance.

Readily Accessible Adjustments—Zero adjustment made from front of gage. Other adjustments made from rear of gage.

Two-point Positive Mounting—Gage unit mounted with two clips . . . no holes to drill or studs to weld.

Unlimited Indications—Any number of basic two-indicator units may be placed side-by-side to provide indications of related factors. Each two-indicator unit is separately mounted.

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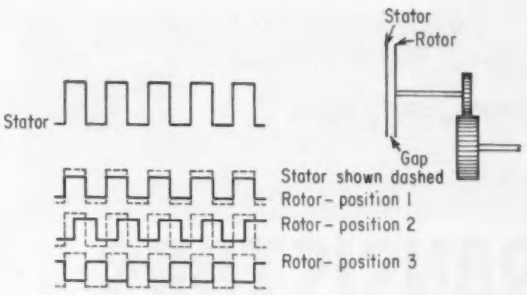


FIG. 2.
Relative positions of square wave patterns printed on rotor and stator of digitizer determine amplitude of output.

this amplitude variation per revolution. The transducer is geared to the lead screw to produce a single cycle for each 0.0002 in. The output of the stator is demodulated to produce a dc signal varying with the amplitude of the stator sine wave. This dc signal is then used to trigger a flip-flop which generates a square-wave train of pulses in which each pulse represents 0.0002 in. travel of the lead screw. These feedback pulses will then be counted, with opposite sign, with the command pulses in a bidirectional counter. The difference between number of command pulses and number of feedback pulses is the servo error and is converted to an analog signal for the hydraulic servo.

As shown in Figure 1 the digitizer actually has two outputs which are 90 deg apart; that is, there are two patterns on the stator disc. The synchronizer block in Figure 1 does several things. First, it synchronizes the feedback pulses from the digitizer to be counted between the command pulses and thus prevents miscounting due to simultaneous arrival of pulses. It also contains logic to determine the direction of X-axis change from the sequence in which the two 90-deg phase signals from the digitizer go positive and negative with respect to the command pulses.

Pop-Up Models Program Ingot Soaking

L. N. BRAMLEY
British Iron and Steel Research Association

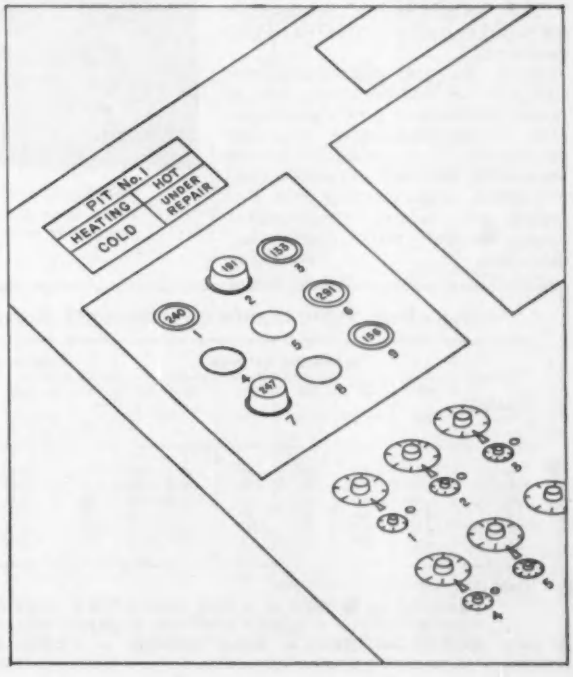
The soaking of cast steel ingots prior to rolling requires careful timing. Too long a soak in the heated pit wastes gas, and the consequent scale formation loses ingot material. Insufficient soaking gives incorrect temperature distribution on the ingot which may cause damage during rolling.

A simple simulation setup called the Ingot Master will be used to provide the soaking pit operator with a sequential display of ingots ready for drawing from the pit. Each soaking pit in the plant is represented by a cutout panel on the desk top containing ¾-in. diam holes 3 in. deep laid out to simulate ingot configuration in the pit. One of these panels is shown in the diagram. At the base of each hole is a pushbutton. Ingots are represented by ⅝-in. diam white plastic rods 3 in. long. As the actual ingot arrives in the soaking pit, the Ingot Master operator codes a plastic cylinder with identification symbols and inserts the simulated ingot into the appropriate pit location. The miniature ingot sets the pushbutton at the base of the hole and rests flush with the desk top, indicating that the pit location is full and heating.

The time for which the particular ingot is to be heated depends on its initial condition. The operator sets the soaking time required on two time dials calibrated in hours and $\frac{1}{10}$ hours. Operation of the timing switch and the base mounted pushbutton connects a master digital clock with output pulses every 6 min.

When the preset time elapses, the final digital pulse releases the pushbutton, and the ingot pops up ½ in. clear of the desk, indicating readiness for drawing, simultaneously illuminating a sequential display showing the order of ingot withdrawal.

While designed primarily for soaking pit operation, the same system is applicable to annealing furnaces.



Plastic cylinders representing steel ingots pop up on soaking pit operator's desk after preset soaking time.

EXTRA QUALITY AT NO EXTRA COST WITH BENDIX TRANSISTORS

Bendix Bulletin

Up-to-the-minute news about transistors

NEW DRIVER TRANSISTORS SWEEPING THE FIELD

Extra-versatile Bendix units beat high costs, design limitations over wide front

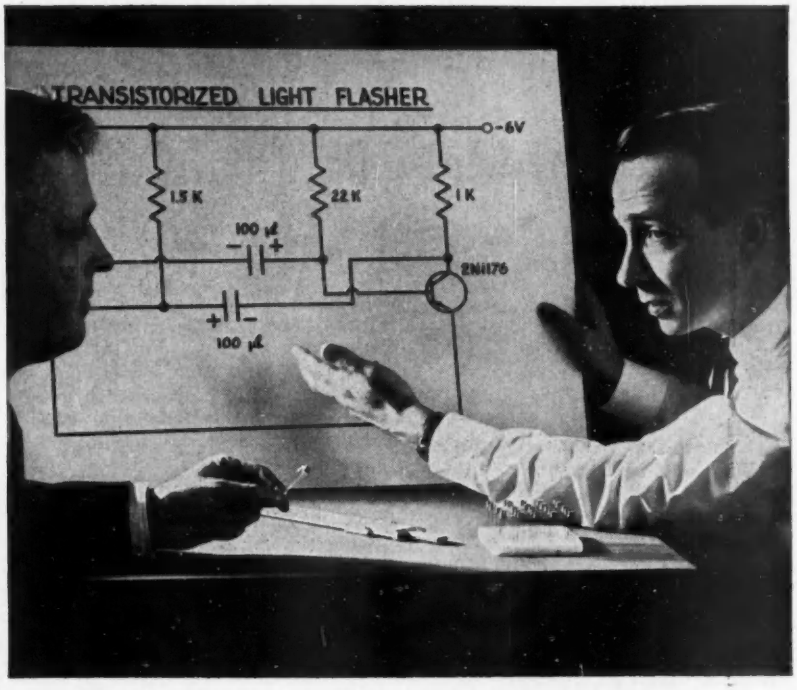
Called the "workhorse of the transistor industry," the new Bendix* Driver Transistor series is winning the nod from more and more engineers daily. These men find it the answer to audio frequency and switching applications requiring extra performance without extra cost.

Here is a special device for use where reliability, versatility, and low cost are primary requirements. The Bendix units combine higher voltage rating and high current gain with more linear current gain characteristics for low distortion and more efficient switching.

They're now in high production for rapid delivery in JEDEC TO-9 packages.

NEW BENDIX SEMICONDUCTOR CATALOG on our complete line of power transistors, power rectifiers, and driver transistors available on request. Write SEMICONDUCTOR PRODUCTS, BENDIX AVIATION CORPORATION, LONG BRANCH, N. J. For information about employment opportunities write personnel manager.

*TRADEMARK



ENGINEERS KNOW the new Bendix Driver Transistor line-up meets an unusually wide range of circuitry applications. Bendix Applications Engineering Department suggestions on circuitry problems are helpful, too.

APPLICATION, PERFORMANCE DATA INDICATE BROAD USAGE

TYPE NUMBERS	MAXIMUM RATINGS					TYPICAL OPERATION		
	Vce	Ic	Pc	Tj	T storage	hfe	fαb	Vce(Sat)
	Vdc	mAdc	mW	°C	°C	Ic = 10 mAdc		Ic = 100 mAdc Ib = 10 mAdc
2N1008	−20	300	400	85	−65 to +85	90	1.2 mc	0.15 Vdc
2N1008A	−40	300	400	85	−65 to +85	90	1.2 mc	0.15 Vdc
2N1008B	−60	300	400	85	−65 to +85	90	1.2 mc	0.15 Vdc
2N1176	−15	300	300	85	−65 to +85	65	1.2 mc	0.15 Vdc
2N1176A	−40	300	300	85	−65 to +85	65	1.2 mc	0.15 Vdc
2N1176B	−60	300	300	85	−65 to +85	65	1.2 mc	0.15 Vdc

Ideal for such applications as:

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NEW PRODUCTS

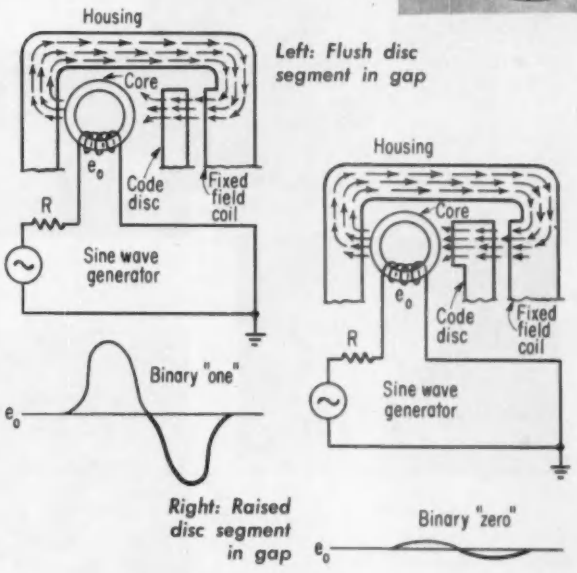
MAGNETIC ENCODER TECHNIQUE boosts input speed and life expectancy.

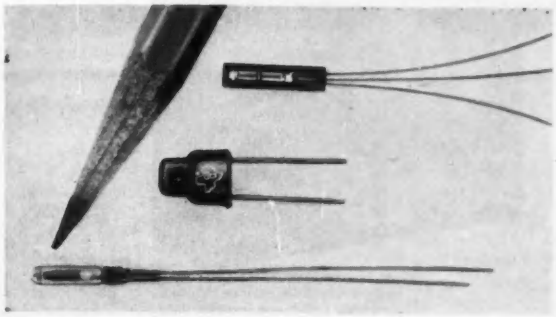
Input shaft speeds to 10,000 rpm, operating lives in excess of 20,000 hours, increased reliability, and a wide temperature range are the chief advantages claimed for a new line of shaft position encoders. Originally developed for use in shipboard fire control systems, these units operate on a magnetic technique which has now been successfully applied to 7-, 13-, 17-, and 19-bit models. Photo at right shows a typical 7-bit model; insert illustrates its ultrasonically machined ferrite code disc with alternately raised and flush segments in the coded pattern.

Instead of brushes the magnetic encoder uses tiny ferrite cores to sense angular position of the driven disc and generate two-level voltage signals that can arbitrarily be designated as binary "zeros" and "ones". Simplified sketches below photos show how its housing, field coil, code disc, and one of its cores form a magnetic path at the reading line. The core is excited by an alternating voltage source, and the polarity of its field is opposite that of the fixed field. As the disc rotates, the magnetic induction of the core is altered in accordance with the coded pattern. When a flush segment of the code disc track passes the core, as in the left-hand sketch, the fixed field flux density drops, magnetic induction of the core increases, and the voltage drop across the core winding goes up, corresponding to a binary "one". Coversely, when a raised segment of the track shares the gap with the core, as in the right-hand sketch, opposition of the fields lowers the impedance of the core winding, and the output voltage then corresponds to a binary "zero."

Units can be supplied with a wide range of digital codes including true binary, Gray, and binary coded decimal. To eliminate the ambiguity problem, V-scan reading techniques are used with all binary coded patterns.—Librascope Div., General Precision Inc., Glendale, Calif.

Circle No. 280 on reply card.





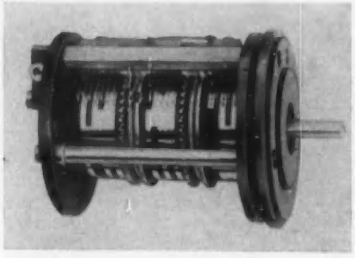
SILICON SENSORS hit the market.

Pictured are three new photovoltaic silicon sensors now available in production quantities. Models include (from top to bottom) the LS-221, a null-sensing device consisting of two matched sensors mounted in a subminiature case and wired to indicate a null when an equal amount of light falls on each sensor; the LS-223, a vertical card reading type with metal case, built-in lens, and a 300-microamp output at 1,250 ft-candles; and the glass encased LS-222, a horizontal card reading type with a slightly lower output.—Texas Instruments Inc., Dallas, Tex.

Circle No. 281 on reply card

NEW PRODUCTS

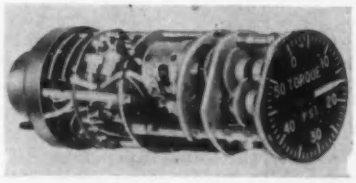
DATA HANDLING & DISPLAY



SERVO-MOUNTING

Designed for direct integration with Size 15 servo components, this Type 18-1077 miniature analog-to-digital converter measures 1.437 in. in diam by 1 1/8 in. long. It requires 100 revolutions of its input shaft to complete its entire code from 0 to 999. Angular bit length is 18 deg; accuracy is said to be within ½ bit at any point in the entire range. Maximum rated input speed is 400 rpm. Applications include fire control, navigation, and other airborne systems.–Courter Products Div., Model Engineering and Manufacturing, Inc., Huntington, Ind.

Circle No. 282 on reply card



MODULARIZED SERVOS

A new method of assembling protoype and limited production servo indicators uses standard stock parts in a simplified, modular construction. The basic module is a gear box in which up to seven 0.0937-in. diam shafts are mounted in ball bearings. With Precision 2 stock gears, ratios of up to 65,000 to 1 are obtainable. Standard plates permit mounting either Size 8 or Size 10 rotating components on the component module. Another module, the dial section, also uses standard parts. Dial configurations to customer specs are photographically processed to give accuracies to 6 min of arc. Use of silicon diodes and transistors and high temperature tantalum capacitors allows units to reach MIL-E-5272 environmental standards. – Servo Development Corp., Westbury, N. Y.

Circle No. 283 on reply card

COMPACT TRANSLATOR

The low cost TR-702 gives the reliability of a Gray code encoder alone with a parallel binary output with complement. A solid state translator, this device will translate up to 14 bits of Gray code to binary code, producing the binary signal's complement at the same time. The encoder output is filtered and clipped, eliminating errors due to brush bounce. Four units can fit in a standard 8¾ x 19-in. panel, each being 4¼ in. wide, 6¾ in. high, and 6¼ in. deep.–Datex Corp., Monrovia, Calif.

Circle No. 284 on reply card

BOTH ANALOG AND PULSE

A new video band recorder reproducer records analog and pulse signals even though its price is in the range of more standard instrumentation equipment. At all speeds (it has six: 7½ to 120 ips) the CM-100's frequency response is twice that of similar equipment. It's 1 Mc at 120 ips, 125 kc at 15 ips, for example. Bandwidth is 400 cycles to 1.0 Mc per track. The ½-in., 7-track tape system is housed in one standard size rack.–Mincom Div., Minnesota Mining & Mfg. Co., Los Angeles, Calif.

Circle No. 285 on reply card

FAST OPERATOR

The 2003 computer, a new solid state, 36-bit, parallel, stored program machine designed for sophisticated computing, combines high reliability at moderate cost. Compared to machines of comparable cost, the 2003 operates much faster–10,000 operations per sec. Features include 64 plug-in in-

struction cards, each with a programmed order; two 64-word magnetic core buffer systems; capability to transfer a 64-word block on a single instruction; and very low power requirements. Memory is 4,096-word core.—Mechanical Div., General Mills, Minneapolis, Minn.

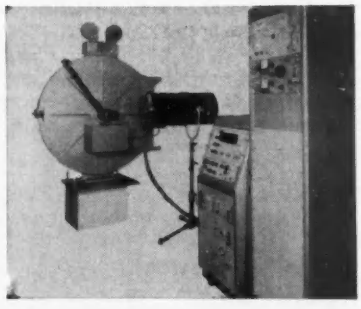
Circle No. 286 on reply card

PLUS. . . .

(287) **Bowmar Instrument Corp.**, Fort Wayne, Ind., offers a new miniature **elapsed time indicator** that displays up to 999 hours in ⅛-in. numerals, making instant readings possible from up to 6 ft away. . . . (288) The RPC-9000 computer, a new electronic **data processing system** available from **Royal Precision Corp.**, Port Chester, N. Y., will handle a wide range of data processing needs and is priced at $120,000 or rented at $2,450 a month.

Circle No. 287 or 288 on reply card

RESEARCH, TEST & DEVELOPMENT

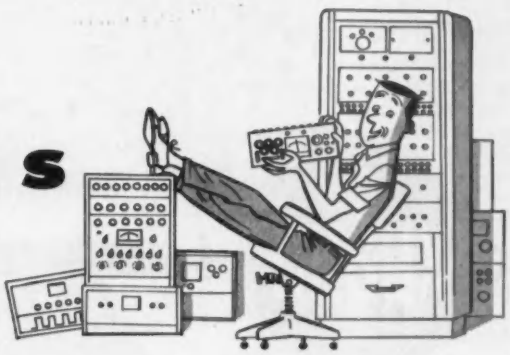


MAGNIFIES TIME BY 100,000

A new movie camera, shown above with camera and light controls and electronic flash lamp, developed by Dr. Albert T. Ellis of Cal Tech, stretches what takes place in one second to 28 hours. Now in production, the ultrahigh speed camera takes from 480 to 1,600,000 pictures per sec on 35 mm film. Effectively freezing motion for research investigations of high speed phenomena like arc discharges, explosive reactions, etc., the camera employs a combination of optical, electronic, and mechanical principles to achieve the speedy pho-

ANALOG COMPUTERS

—How You Can Use Them



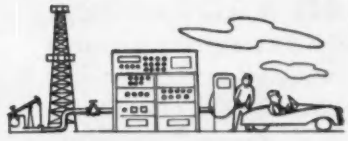
It's no secret that people who make analog computers spend a lot of time talking to each other. Pity the chap who's trying to figure out how all this palaver applies to him. He's in a semantic jungle.

First, let's define what kind of computers we're talking about. At Donner, we're concerned with two types—general purpose and fixed purpose. Quickly, general purpose analog computers solve equations describing lumped parameter, dynamic systems expressed in linear or non-linear differential equations, or transformed (La Place) equations. They are used to directly simulate systems described by these equations. They are also used to analyze sections of these systems. In other words, this type of computer gives you freedom and flexibility limited only by your imagination.

THE FIXED PURPOSE COMPUTER

Actually, there's not much difference between general purpose and fixed purpose computers. The point is that fixed purpose computers fit neatly into your system to do a specific job. You don't have to worry about programming—that's built in. All you do is turn the knobs. It may interest you to know that 80 to 90 per cent of analog computing equipment sold is fixed purpose. At Donner, fixed purpose gear is one of our big specialties. It comes in a wide variety of sizes. Typical of lightweight devices is the solid state "think" device developed by Donner for the Polaris missile which monitors flight performance. If, for example, in the initial portion of the flight, the missile does not achieve sufficient velocity by a predetermined time, the Donner system aborts the flight. The missile gets the go-ahead only as programmed.

Another fixed purpose computer is the on-line wind tunnel data reduction computer recently built by Donner for the National Research Council of Canada. This computer receives, processes, and analyzes signals from force transducers mounted on a scale model. Such coefficients as lift and drag are continuously and simultaneously studied.



COMPUTERS FOR ANALYSIS ARE OFTEN USED

Fixed purpose analog computers are used in linear and non-linear programming. Here, they solve problems of gasoline blending, game theory, logistics, military tactics, and operations research.

Other fixed purpose analog computers are used to study spectral density and variation coefficients. The spectral density computer is used to make vibration, noise and system transmissibility studies. Statistical evaluation of non-continuous or discrete process can be performed with variation coefficient computers. In this application, achieved values are put in and average value, standard deviation, and variation coefficient instantly computed out.

COMPUTERS FOR INFORMATION CONTROL, SIGNAL CONDITIONING, AND PROCESSING

Three other examples of fixed purpose analog computers in use are a missile tracking computer, signal conditioning computer, and process control computer.

The missile tracking computer receives distance and angular displacement information from tracking radars. From this information, the computer provides a continuous plot of the missile's position in cartesian coordinates.

Signal conditioning computers modify frequency, phase or amplitude to restore or control signal characteristics. They are used for hybrid computer links, preamplification of low level transducer signals, spectrum segmentation with active filters, or automatic control of dynamic range.

Process control computers receive signals from transducers, linearize the signals, compare them with set points both fixed and variable, and provide control signals with rate, reset, and proportional adjustments.

LET'S HEAR FROM YOU

Enough talk. We've given you a rough idea what Donner has done for other people. Let's find out how this applies to you. Send us a brief description of your problem; a paragraph or two will do. We'll write back telling how Donner can help and send you a Tech Note if it applies. If writing's a chore, our engineering rep will be happy to discuss methods of solving your problem with Donner's computer systems. Just contact us for his name. Either way, you'll get information that applies to your particular problem. Please address Dept. 21.

DONNER SCIENTIFIC COMPANY

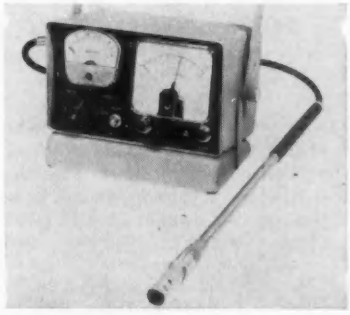
CONCORD, CALIFORNIA

26

NEW PRODUCTS

tography. – Benson-Lehner Corp., Santa Monica, Calif.

Circle No. 289 on reply card



GAS DETECTOR

Usable as a portable instrument with a probe-type element or as a fixed indicator alarm, the new device shown above gives alarm when gas concentrations reach unsafe levels. For portable use a built-in battery (with charger) provides power. For stationary use a 110-vac source can be used; the detector element can be up to 100 ft from the indicator. Case is lightweight (12 lb.) and small (5 x 7 x 8 in.) and has provision to store two spare detector elements for quick replacement. Cost is $425.–Houston Instrument Co., Houston, Tex.

Circle No. 290 on reply card

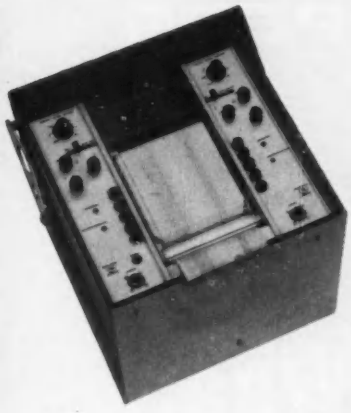
LOCATES INTERFACES

Long lead lengths provided for the new A+ Thermophil instruments permit accurate measurements of liquid temperatures at depths to 1,000 ft. By measuring the temperature layers in stratifications of different liquids, the various strata can be pinpointed to maintain quality control and uniformity. Temperature ranges from minus 148 to plus 554 deg F are available. The Model 4416/4, with a range of plus 32 to 122 deg F, indicates sub-

keep an accurate graphic record

OF RESEARCH, DESIGN, TEST DATA

two channels



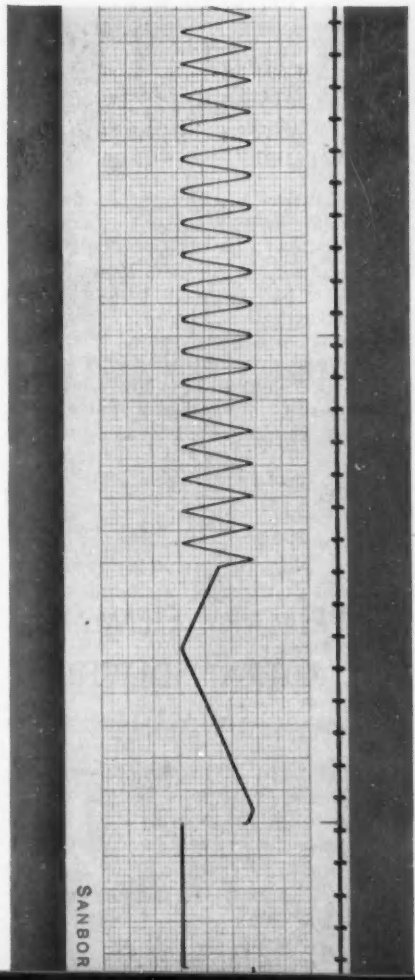
For General Purpose DC Recording — Model 320

For recording *two variables* simultaneously, the Model 320 provides a versatile, transistorized amplifier for each input signal. The rugged 2-channel recorder assembly has heated stylus recording on two *50 mm wide* rectangular coordinate channels, 4 pushbutton chart speeds, and 6 inches of visible chart. The Recorder can be placed vertically, horizontally or at a 20° angle.

MODEL 320 SPECIFICATIONS

Sensitivity: 0.5, 1, 2, 5, 10, 20 mv/mm and v/cm
Frequency Response: 3 db down at 125 cps, 10 mm peak-to-peak
Common Mode Voltage: ±500 volts max.
Common Mode Rejection: 140 db min. DC
Calibration: 10 mv internal ±1%
Output Connectors for each channel accept external monitoring 'scope or meter
Price: $1495

NEW SANBORN PORTABLE DIRECT WRITING RECORDERS FOR IN-PLANT, LABORATORY OR FIELD RECORDING



Two models of this 21 lb. brief case size recorder are available — Model 301 for AC strain gage recording, Model 299 for general purpose DC recording. Both provide immediately visible, inkless traces by heated stylus on 40 division rectangular coordinate charts . . . frequency response to 100 cps . . . 5 and 50 mm/sec chart speeds . . . approx. 4 inches of record visible in top panel window.

single channel

MODEL 301 SPECIFICATIONS

The amplifier section of the Model 301 is an all-transistorized carrier type with phase sensitive demodulator. The power supply and internal oscillator circuits are also transistorized.
Sensitivity: 10 uv rms/div (from transducer)
Attenuator Ratios: 2, 5, 10, 20, 50, 100, 200
Carrier Frequency: 2400 cps internal
Transducer Impedance: 100 ohms min.
Calibration: 40 uv/volt of excitation
Output Connector: for external monitoring 'scope or meter
Price: $750

MODEL 299 SPECIFICATIONS

Combines the dependability of transistors with the high input impedance of vacuum tubes for reliable broad-band DC recording.
Sensitivity: 10, 20, 50, 100, 200, 500 mv/div and 1, 2, 5 and 10 v/div
Input Resistance: 5 megohms balanced each side to ground
Common Mode Voltage: ±2.5 volts max. at 10 mv/div sensitivity increasing to ±500 volts max. at other sensitivities
Common Mode Rejection: 50:1 most sensitive range
Calibration: 0.2 volt internal ±1%
Output Connector: for external monitoring 'scope or meter
Price: Model 299 (with zero suppression) $700
Model 299A (without zero suppression) $650

All prices are F. O. B. Waltham, Mass., within continental U. S. A. and are subject to change without notice.

Contact your Sanborn Sales-Engineering representative for complete information, or write the main office in Waltham. Sales-Engineering representatives are located in principal cities throughout the United States, Canada and foreign countries.

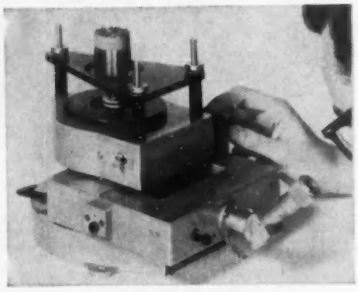
SANBORN COMPANY
INDUSTRIAL DIVISION
175 Wyman Street, Waltham 54, Mass.

CIRCLE 165 ON READER SERVICE CARD

NEW PRODUCTS

merged temperatures to within 0.25 deg.–Atkins Technical, Inc., Cleveland, Ohio.

Circle No. 291 on reply card



PRODUCTION TEST STAND

The Model 7530 test stand shown in use above is a precision shaft positioning device. Used for production tests of resolvers, synchros, potentiometers, and other rotating electromechanical equipment, it is based on an optical coincidence reading system with plus or minus 2 sec of arc error, a rack and pinion gear for shaft positioning, and an adaptor plate and coupling.–W. & L. E. Gurley, Troy, N. Y.

Circle No. 292 on reply card

DIRECT ERROR READING

Possibility of ambiguous readings, reading wrong range, or miscalculating deviation from an absolute value is eliminated in the new Model DVM-300 digital deviation ohmmeter that automatically measures resistance around a nominal value. The information is presented in digital form as a direct percentage of this value. The new meter reads plus or minus 5 percent of the total resistance with an absolute error of 0.01 percent.–Electro Instruments, Inc., San Diego, Calif.

Circle No. 293 on reply card

PRIMARY ELEMENTS & TRANSDUCERS

PATENTED WIPER ARM

The TI-P-MH Series potentiometer pressure transducers feature a new lightweight wiper arm which is electromagnetically held in contact with

JOURNAL OF APPLIED CONTROL DEVICES THAT NEVER WEAR OUT

For Control Engineers Who Are Wearing Out Before Their Time

FREEZING A MOLTEN WILL-O'-THE-WISP (to ±¼° at 2200°F)

Pittsburgh Plate Glass Company freezes molten glass temperatures at 2200°F to within ±¼° as it extrudes fiber glass so fine that 1700 miles of it weigh but one pound! How? PPG has selected CPM-1 Temperature Controllers made by Hagan Chemicals & Controls, Inc. The Hagan systems (over 200 of them have been ordered) not only set a new order of uniformity for glass fiber diameters, but are virtually wear-proof. They achieve this doubly profitable result by use of static control elements: there are no moving parts, and only one vacuum tube device in the entire system! An integral part of the CPM-1 unit is a CONTROL Proportioning Reactor with six control windings. It receives a proportional signal, a reset signal and a rate signal, and provides both current limiting and manual control. *"Rugged and able to handle multiple signals, yes," said Hagan engineers, "but what about sensitivity?" When we showed them the proportioning reactor's 2-milliampere windings, there were no more questions. However, we'll be happy to answer any you may have.*

Figure 1. Hagan CPM-1 Temperature Controllers. Square Boxes are CONTROL Proportioning Reactors.

ON YOUR BOBBIN, RESET, GO!

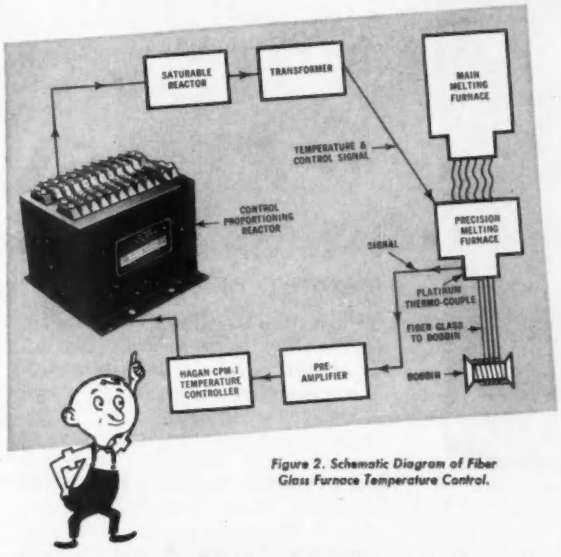


Figure 2. Schematic Diagram of Fiber Glass Furnace Temperature Control.

Fiber glass is pulled through a die in the bottom of a "bath tub" of molten glass at more than 3 miles per minute. It is wound on a bobbin, and when a "package" is completed, the operator has 15 seconds to change bobbins and restart the operation. There is as much as a 15° temperature upset in the system, yet when the winder restarts, the controller must reset the temperature at 2200° within ±¼° in the allotted 15 seconds. The CONTROL reactor puts out 100 watts at 80 volts, sufficient power to drive the saturable reactor ahead of it, and is at the instant beck and call of rapid and minute changes in signal. The response of the overall Hagan system is better than 0.1 seconds at full output. *When the first tests were run, accuracy of control was found to be even better than the ±¼° anticipated. Should you wish to learn more about these satisfactions with static control via our proportioning reactors, we'll be happy to answer your request for intimate details.*

STATIC CONTROL: (flexible and standard)

The function CONTROL Proportioning Reactors play in a system (the Hagan Temperature Controller is a telling example) is unique. The designer—for process control, for machine tool control, for assembly line control, for almost any control—can feed a variety of input signals into several isolated control windings in each proportioning reactor, and sum them to provide an amplified control signal. The reactor's figure of merit (ratio of volt-ampere amplification to time of response) is exceptional. It is as high as 1,500 for an N_C^2/R_C of 1,800. Thus, there is both power and sensitivity for the designer who works with static control. *Want to know who else among the nation's leaders have joined production-smart Pittsburgh Plate Glass in the swing to static control? We'll be happy to tell you—and to help with your static control ideas.*

Reliability begins with CONTROL®

A DIVISION OF MAGNETICS INC.

DEPT. CE-79, BUTLER, PENNSYLVANIA

NEW PRODUCTS

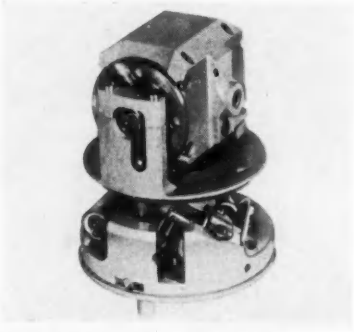
the mandrel only during the readout period. This eliminates much of the shock, vibration, and wear associated with heavier spring-loaded wipers.

Characteristics:

Pressure ranges: to 100 psia or psig
Resistances: 5,000, 7,500, or 10,000 ohms
Linearity: within 0.75 percent
Resolution: 0.3 percent
Thermal response: under 0.02 percent/deg F

—Physical Sciences Corp., Pasadena, Calif.

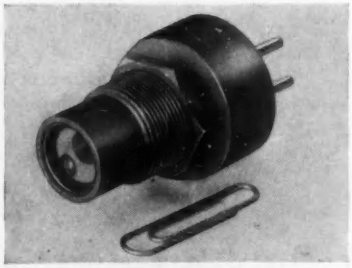
Circle No. 294 on reply card



TWO DEG OF FREEDOM

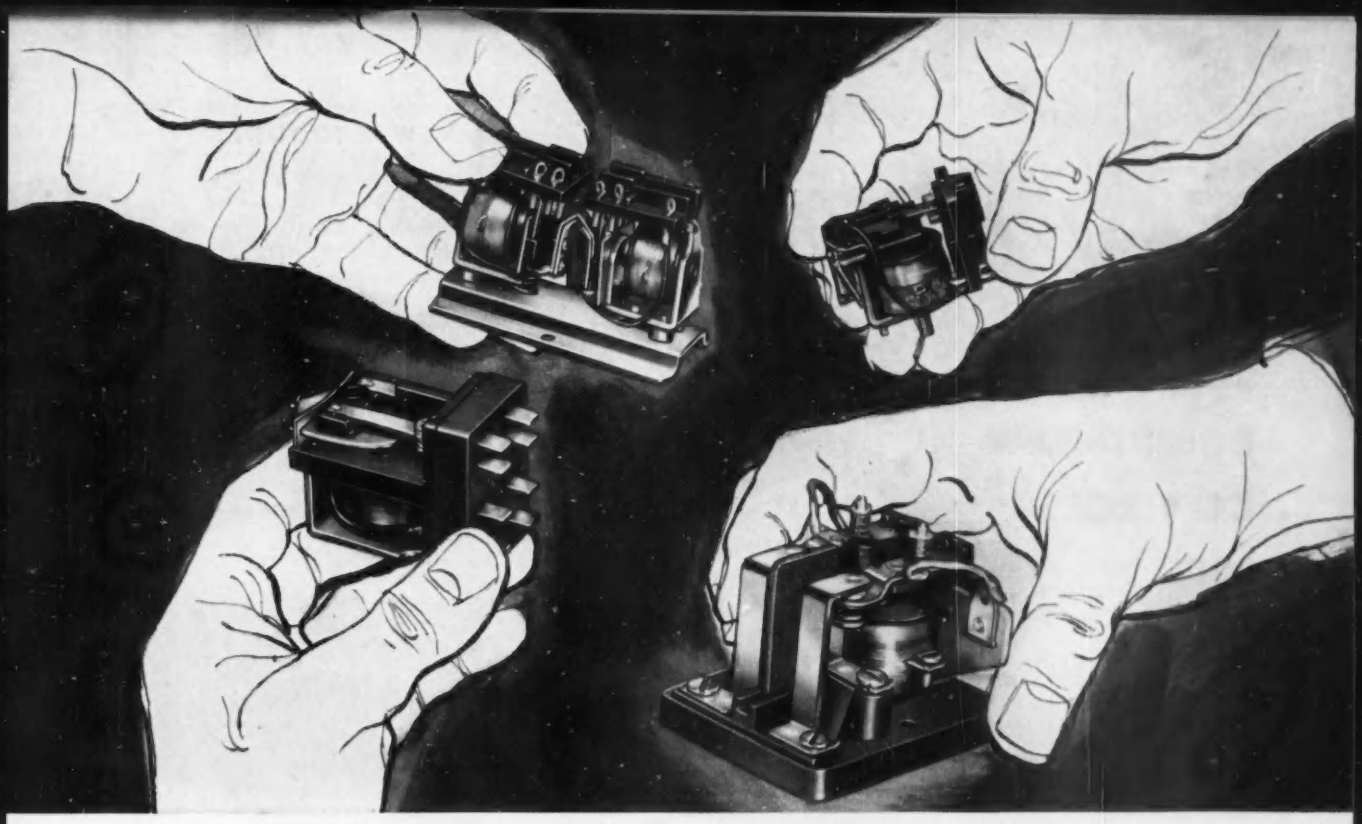
Designed to save weight and space without sacrificing accuracy and dependability, this new miniature electric gyro is only 2 in. in diam and 2.5 in. high. It weighs only 250 gm but is rugged, maintaining its accuracy under severe conditions. The two deg of freedom unit is said to have a maximum Scirsby drift of 1 deg per min, with outer gimbal readout.—Greenleaf Mfg. Co., Div. of Mandrel Industries, Inc., St. Louis, Mo.

Circle No. 295 on reply card



PROXIMITY PICKUP

With energy source and detector combined in a single unit just 2¼ in. long by 1⅛ in. in diam, this new infrared



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These important savings are yours when you order—from your Electronic Parts Distributor—P&B relays listed with Underwriters' Laboratories, Inc. and Canadian Standards Association:

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More than 40 different standard P&B relays in 450 different coil voltages and contact arrangements are available from the leading Electronic Part Distributors in your area. For special applications, call your nearest P&B sales engineer.

PR Series

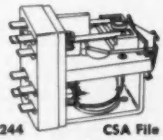
Type	Contact Arrangement*	Type	Contact Arrangement*
PR1AY	SPST-NO	PR5AY	SPDT
PR3AY	SPDT-NO-DM	PR7AY	DPST-NO
		PR11AY	DPDT

These relays are available in any of the following operating voltages: 6, 12, 24, 115, 230 volts 50/60 cycles AC.

Contacts are rated at: 25 amps, 115/230 V. AC 1 phase. 1 hp for 115/230 volt AC motors 1 phase.

*Read: NO normally open, NC normally closed, DB double break, DM double make.

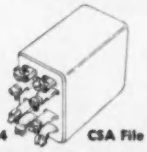
U/L File E22575 CSA File 15734



AB Series

U/L File E29244 CSA File 15734

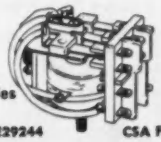
For appliance and general purpose operations requiring long life and quiet operation. Quick connect terminals. Screw terminal adapters also furnished with each relay. Contact arrangement: DPDT. Rated at 10 amps, 115 V., 5 amps, 230 AC non-inductive by U/L and CSA.



ABC Series

U/L File E29244 CSA File 15734

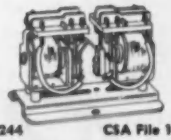
Medium duty power relay in dust cover. For small motors, industrial controls and similar applications. Contact arrangement: DPDT. Rated at 10 amps, 115 V., 5 amps, 230 AC non-inductive by U/L and CSA.



KA Series

U/L File E29244 CSA File 15734

Small, low cost, general purpose relay for handling automation work, small motors, solenoids, other relays. Contact arrangements: SPDT, DPDT and 3PDT. Rated at 5 amps, at 115 V., AC non-inductive by U/L and CSA.



KB Series

U/L File E29244 CSA File 15734

Compact latch relay ideal for memory work and overload applications. Operates on momentary impulse to either coil. Contact arrangements: 4PDT and 6PDT. Rated at 5 amps at 115 V., AC non-inductive by U/L and CSA.

POTTER & BRUMFIELD

DIVISION OF AMERICAN MACHINE & FOUNDRY COMPANY, PRINCETON, INDIANA

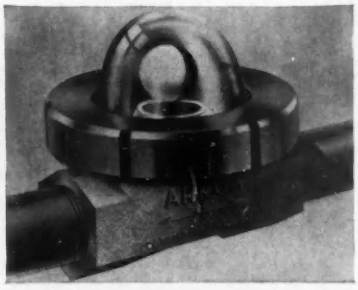
IN CANADA: POTTER & BRUMFIELD CANADA LTD., GUELPH, ONTARIO

CIRCLE 169 ON READER SERVICE CARD

NEW PRODUCTS

photoelectric scanner, Type SA-IR, responds to both metallic and nonmetallic objects and is well suited for a wide variety of counting and control operations. It will sense objects or control areas at distances up to 2 in. When operated at 5 vac, its IR source has a rated life of 60,000 hr. List priced at $29, it features a four-prong base for plug-in connection to its control circuit.—Farmer Electric Products Co., Inc., Newton Lower Falls, Mass.

Circle No. 296 on reply card



BALL INDICATES LOW FLOWS

The simple ball-type indicator shown above provides reliable indication at a glance of where flow is taking place. Flow causes the ball to "dance" in the toughened glass dome; when the flow stops, the ball drops out of sight. Indication is possible at a distance, even in poor light. The Arkon indicator is made in ½-in. pipe size for pressures up to 100 psi. Applications include air, steam, water, and oil purge lines to instruments and mechanical seals; cooling water lines to compressors, lab equipment, etc.; and lubricating oil lines to bearings.— McIntosh Equipment Corp., New York, N. Y.

Circle No. 297 on reply card

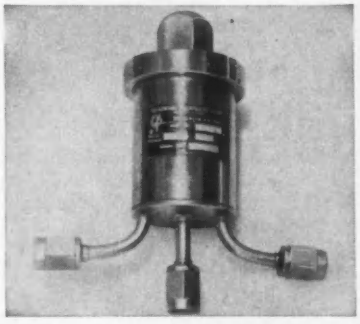
CONTROLLERS, SWITCHES & RELAYS

SELF-CLEANING CONTACTS

Capable of operating directly in the plate circuit of a vacuum tube, a new 6-pole, double throw relay uses a unique wedge action that burnishes all contacts during each operating cycle. The relay's coil operates from 150-200 volts drawing 10-12 ma. Temperature range is minus 65 to plus

125 deg C. In a hermetically sealed, dry nitrogen filled enclosure the relay has no bounce and will withstand 30g vibration to 2,000 cps and 100g shock. —Pacific Scientific Co., Bell Gardens, Calif.

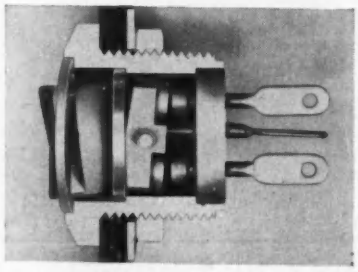
Circle No. 298 on reply card



MAINTAINS STABLE OUTPUT

Suitable for a variety of military and industrial reference pressure applications, this 7½-oz Type 415830 pressure regulator features all stainless steel construction and metal-to-metal seals throughout. Its regulated output, adjustable from 2 to 17 psia, is held within 0.1 percent at temperatures ranging from minus 65 to plus 600 deg F. Unaffected by temperatures as high as 1,000 deg F, the basic unit can be adapted to cover a 100-psia range.—Gladden Products Corp., Glendale, Calif.

Circle No. 299 on reply card



WITHSTANDS ALL

Using the discovery of Reed Research, Inc. that magnetic flux could be conducted along a magnetic path—even through a solid "wall"—and the conclusion that flux could thus be used as a substitute for mechanical linkage, the new FluxLink switches now on the market provide fail-proof switching in virtually any environment. Just ⅜ in. long by ¼ in. in diam, the devices will operate from minus 65 to plus 900 deg F, handling 0.15 amps at 125 vac. In operation, flux is "piped" through a solid metal barrier into a sealed chamber containing the con-

NEW PRODUCTS

tacts. The flux becomes the snap action that operates the contacts.—Space Components, Inc., Washington, D. C.

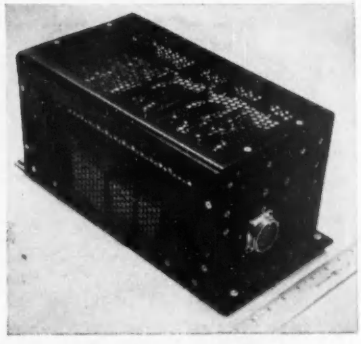
Circle No. 300 on reply card

PLUS. . .

(301) A transistorized **level control probe** for high and low level detection of liquids and granular solids and liquid interface detection is available from **Instruments, Inc.,** Tulsa, Okla. . . . (302) Now in production by the **Auto-Timer Div. of the Sloan Co.,** Sun Valley, Calif., is a 1-cu in. **subminiature timer** with a time delay range up to 60 sec. . . .(303) In a completely encapsulated unit two independent **switching actions and a potentiometer** are provided in a new device announced by **Clarostat Mfg. Co., Inc.,** Dover, N. H.

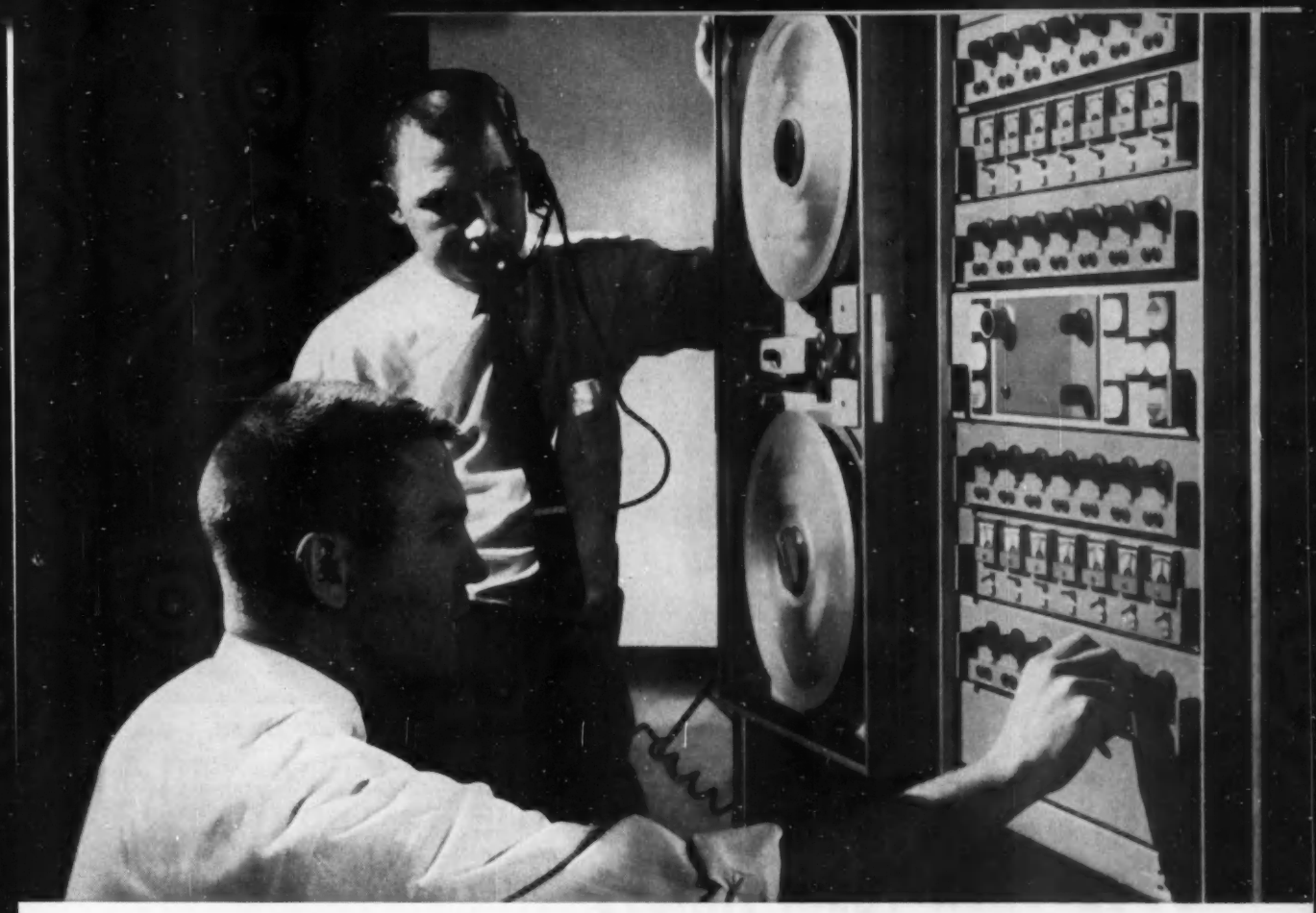
Circle No. 301, 302, or 303 on reply card

POWER SUPPLIES



FOUR-CHANNEL POWER

Originally developed to supply current to the focusing coils of a klystron, this new four-channel power supply can be used as a reference in rotating systems, cyclotrons, large magnetic systems, or wherever a highly regulated current supply is needed. The transistorized unit operates from a 208-volt, 3-phase, 400-cycle input. Outputs with less than 1 percent ripple and regulation to better that plus or minus 0.5 percent are in these ranges: 1.1-1.2 amps at 16.5-33.8 watts, 3-6 amps at 16.2-216 watts, 6-9 amps at 65-292 watts, and 3-5 amps at 27-135 watts.—Industrial Products



AMPEX specifies Tung-Sol transistors for FR-600 analog tape recorder

The Ampex FR-600 records the same bandwidth at half the tape speed previously required. It's the first Ampex laboratory-type instrumentation recorder to offer all solid-state electronics. Frequencies as high as 250 kc can be handled (at a tape speed of 60 ips). FM, pulse-duration modulation, direct and digital recording modes are available through plug-in amplifier modules. FM response from d-c to 20 kc within ½ db is double that previously available. The FR-600 is already handling data recording in the new Minuteman missile project.

With reliability the keyword, the choice of components for the FR-600 had to be an exacting one. Tung-Sol germanium power and switching transistors were specified for several major assignments. Tung-Sol's high stability 2N379 transistors deliver reliable power to the motor drive amplifier, the FR-600 control unit, and each bay power supply of the recorder. Tung-Sol's precision 2N414 germanium switching transistors handle important switching functions in the direct record amplifier, direct reproduce amplifier, FM record, FM reproduce, pre-amplifier and frequency standard.

More and more are Tung-Sol components assuming critical tasks in modern electronics where long-life reliability is paramount. Whether in industrial, military or commercial applications, there's a Tung-Sol tube or semiconductor for virtually every need. Every component is the product of production processes and quality control that have made Tung-Sol the name synonymous with the finest componentry. Tung-Sol Electric Inc., Newark 4, N. J. TWX:NK193

Technical assistance is available through the following sales offices: Atlanta, Ga.; Columbus, Ohio; Culver City, Calif.; Dallas, Texas; Denver, Colo.; Detroit, Mich.; Irvington, N. J.; Melrose Park, Ill.; Newark, N. J.; Philadelphia, Pa.; Seattle, Wash. Canada: Toronto, Ontario.

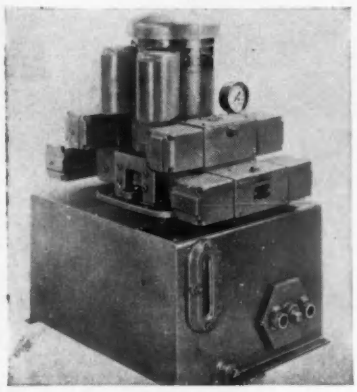
TUNG-SOL®

CIRCLE 173 ON READER SERVICE CARD

NEW PRODUCTS

Div., International Telephone & Telegraph Corp., San Fernando, Calif.

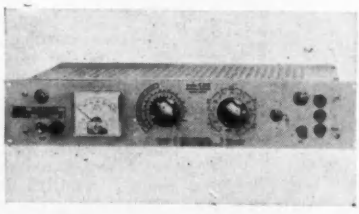
Circle No. 304 on reply card



INCLUDES THE VALVES

New addition to the CircuitPak line of preengineered and packaged hydraulic power units, this particular model consists of a 10-gal reservoir, electric motor (1, 1½, or 2 hp), and from one to four solenoid-controlled, four-way directional valves. Pumps with capacities of 1, 1½, and 3 gpm are available. To provide automatic unloading, valves are mounted in series. Unit has no external piping and is equipped with a built-in relief valve for system protection. Built-in water-oil heat exchanger is optional.—Double A Products Co., Manchester, Mich.

Circle No. 305 on reply card



PROGRAMMABLE POWER

A multistep range selector and continuous vernier control permit "programming" this new series of constant current sources for applications like semiconductor diode testing, transistor production testing, and gyro compensation, among others. Voltage compliance ranges from 100 volts at maximum current to as high as 260 volts in one model.—Electronic Measurements Co., Inc., Eatontown, N. J.

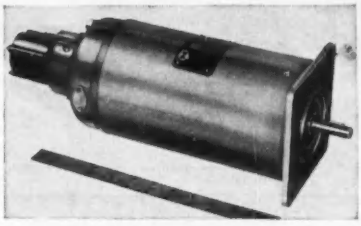
Circle No. 306 on reply card

ACTUATORS & FINAL CONTROL ELEMENTS

REDESIGNED ACTUATOR

A new motorized actuator for relief valve and pump control applications, the P/N11101 will control and modulate up to 5,000 psi hydraulic pressure with only 15 watts electrical input power. Features of the new design include: spline drive from the motor through to the rotating plunger, an open "C" frame limit switch housing, an anti-backlash adjustment, and improved wire routing. Limit switches may be set for full open and closed positions or for any two preselected pressures. Standard unit operates on 28 vdc.—United Control Systems, Inc., Dayton, Ohio.

Circle No. 307 on reply card



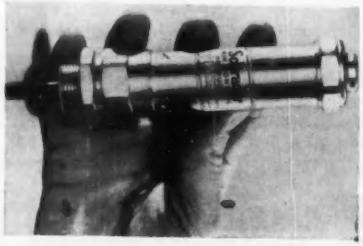
HAS HIGH RESPONSE

Intended for industrial applications requiring rapid starts, stops, and reversals, this new line of high response dc servomotors is available in sizes from ¼ through 1 hp.

Characteristics:

Reversal time: 0.28 sec (from +3900 to −3900 rpm)
Speed range: up to 400 to 1
Weight: 47 lb
Overall length: 11⅜ in
—Reliance Electric & Engineering Co., Cleveland, Ohio.

Circle No. 308 on reply card

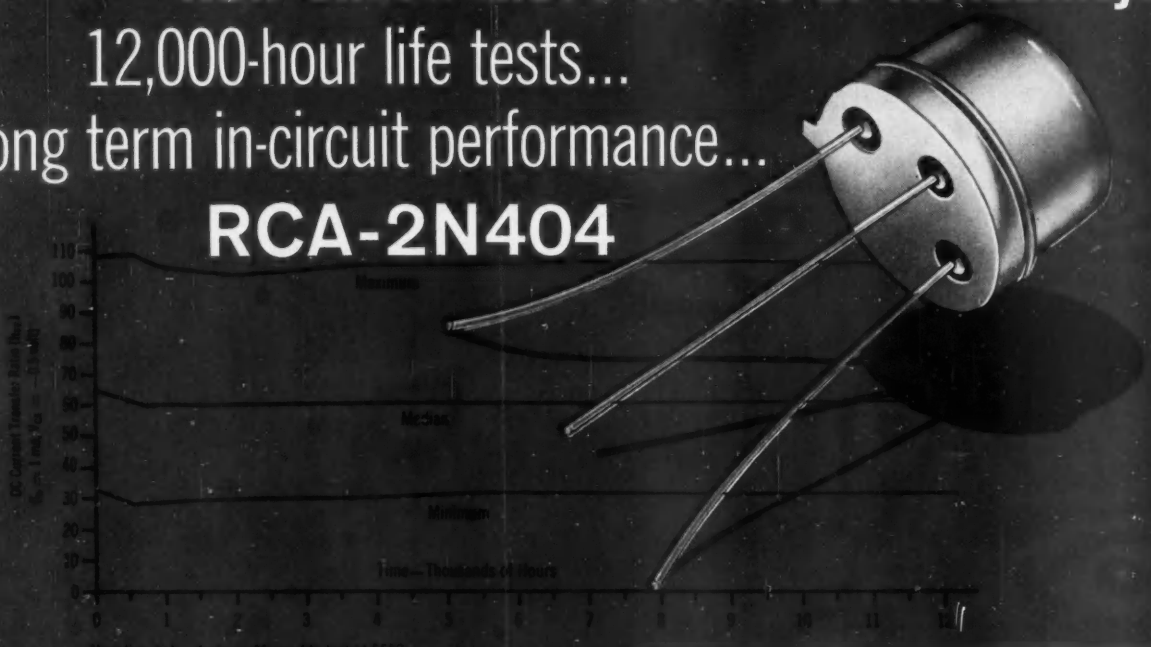


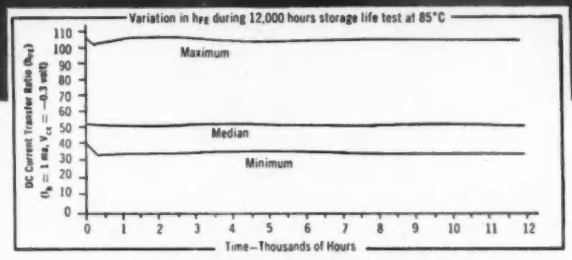
MAX IN MIN

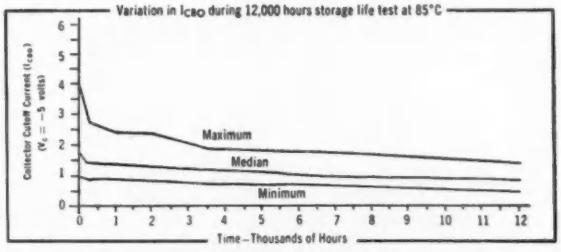
Shown above is one of new series of midget air cylinders that are designed to supply maximum power in mini-

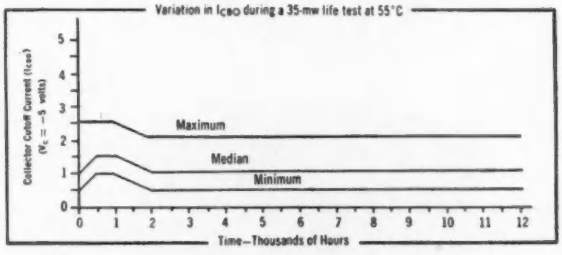
Now Check these Proofs of Reliability...

12,000-hour life tests...
long term in-circuit performance...
RCA-2N404









The transistor that helped build an industry ...designed, built and introduced by RCA... chosen by top manufacturers for the finest computers...the RCA-2N404 has set new standards of reliability for transistorized computers

Outstanding new achievements of operating reliability, long life, and stability are being made by the RCA-2N404 germanium p-n-p medium-speed switching transistor. Stringent long-term life tests and dynamic in-circuit performance checks, both at maximum ratings, provide additional proof of the bedrock reliability of the RCA-2N404.

Here are the results:

(1) Representative samples of the RCA-2N404 computer transistor have now passed 12,000 hours of operating life at *maximum* ratings. The curves at the right show the remarkable stability of transistor parameters over this exceptional time period.

(2) Samples from every lot of RCA-2N404 transistors are tested at *maximum* ratings for 1,000 hours. During 1959, almost 6,000,000 transistor test-hours at 85°C junction temperature were logged.

Why not call your RCA Field Representative today for the full story on the RCA-2N404 and the RCA-2N404 designed to meet military specification MIL-T-19500/20 USAF. For technical information write RCA Commercial Engineering, Section E-56-NN, Somerville, N.J.

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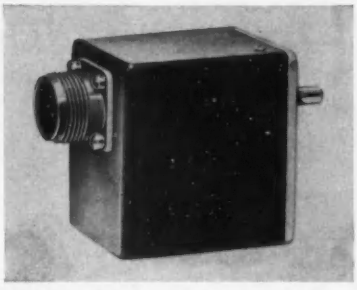
AVAILABLE THROUGH YOUR RCA DISTRIBUTOR

NEW PRODUCTS

mum space. Units are double acting with 1 in. bores, are suitable for up to 125-psig pressures. The six models in the series have strokes of 1, 2, 3, 6, 9, and 12 in. Lengths range from 4$\frac{13}{32}$ for the 1in. stroke model to 15$\frac{13}{32}$ for the 12-in. type.–A. Schrader's Son, Div. of Scovill Mfg. Co., Inc., Brooklyn, N. Y.

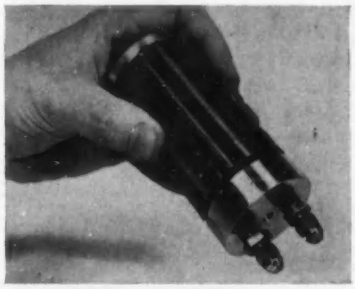
Circle No. 309 on reply card



HANDLE LOADS TO 25 LB-IN.

Photo above shows one of several configurations in a new series of electromechanical rotary actuators featuring compact design, light weight, and high reliability. Units measure 1$\frac{3}{4}$ x 2$\frac{1}{2}$ x 2 in., weigh approximately 12 oz, and contain up to six internal limit switches adjustable for travels from 10 deg to 100 revolutions. Powered by 26-volt dc motors or by 115-volt, 400-cycle, ac motors, these miniature actuators can operate with loads up to 25 lb-in.–Nash Controls, Inc., Newark, N.J.

Circle No. 310 on reply card



WIDE LINEAR RANGE

Designed to overcome the disadvantages of needle valves in low flow applications, this Model F4 Micrometer Flow Control Valve provides a linear 10-fold increase in flow rate, from 10 to 100 cc per min, through 15 complete turns. Beyond this linear range, nine more turns increases the flow to 1150 cc per min. Since rate of flow is based on the length of the flow passage rather than its area, the possibility of clogging at low flows is greatly reduced. Valve may be used wherever needle valves have been used and is particularly suited for use as a variable damping passage in electrohydraulic servosystems.–Sanders Associates, Inc., Nashua, N.H.

Circle No. 311 on reply card

COMPONENT PARTS

SIZE 11 MOTOR

Although designed principally for use in ground support equipment and devices used to test accelerometer functions, this R172 Size 11 synchronous motor should find wide use wherever constant speed is required despite line or load voltage variations. Unit is available with either plain or pinion shaft.

Characteristics:
Operating voltage: 26 volts
Synchronous speed: 8,000 rpm
Frequency: 400 cps
Power required: 3.4 watts
Power factor: 0.38
Stall torque: 0.30 oz-in.
–Kearfott Div., General Precision, Inc., Little Falls, N. J.

Circle No. 312 on reply card

DESIGNED FOR THE MILITARY

Three new silicon power rectifiers, the 1N1614, 1N1615, and 1N1616, have been designed specifically to meet the requirements of MIL-E-1/1240, 1/1241, and 1/1242. Featuring a high reverse voltage characteristic ranging from 200 to 600 vdc, these rectifiers will operate at temperatures as high as

NEW PRODUCTS

150 deg C with a reverse current of only 1 ma. At 10 amps, forward voltage drop is just 1.5 vdc. Case dimensions are set up to conform to the JEDEC DO-4 configuration.—Red Bank Div., Bendix Aviation Corp., Long Branch, N. J.

Circle No. 313 on reply card

VIBRATION NO PROBLEM

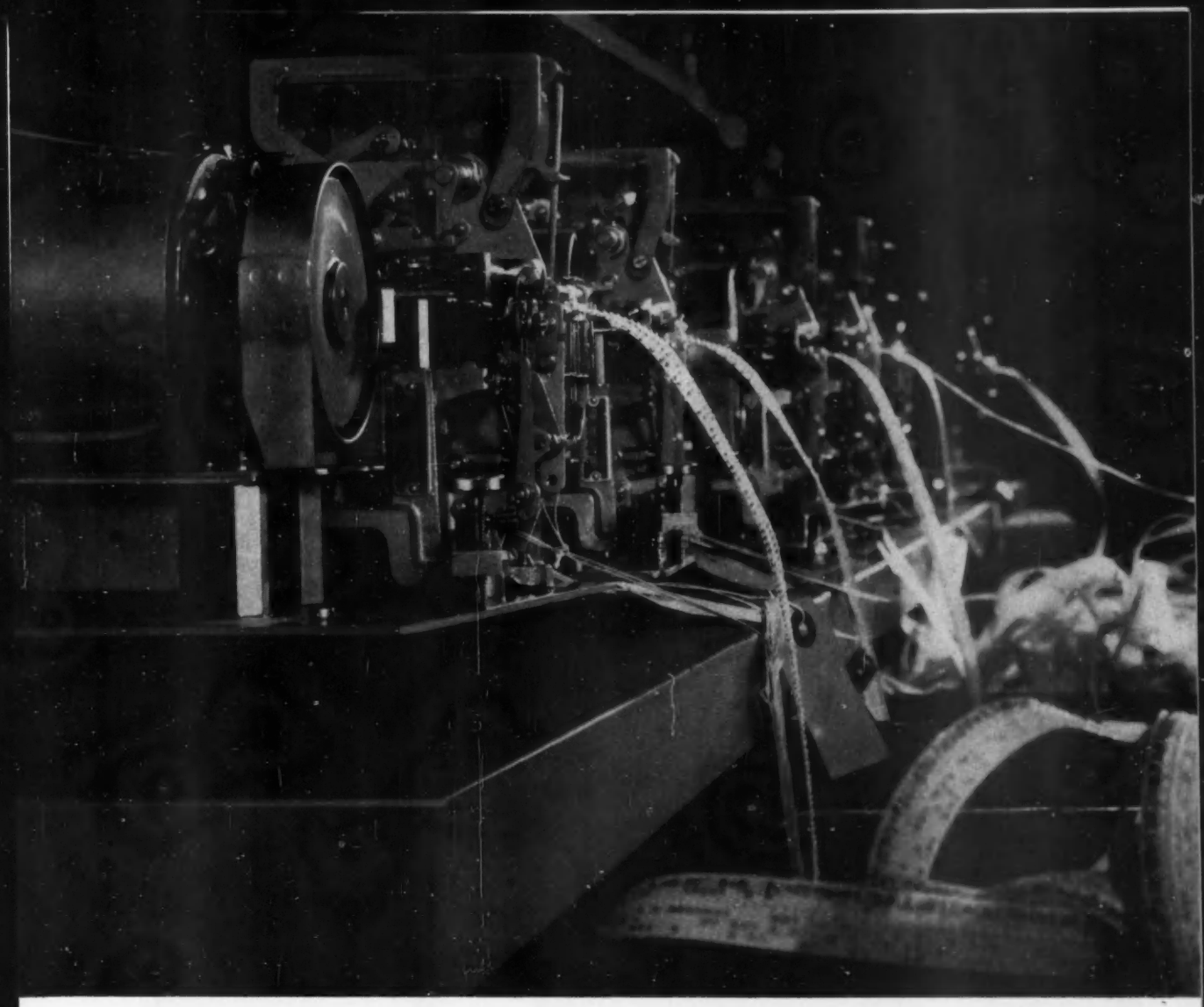
This Model 207G germanium transistor amplifier weighs just 0.6 oz and has a total volume of less than 0.4 cu in. Designed for moderate temperature applications, the unit will withstand 400 g's at 25 kcps without microphonic noise. Its open-loop gain exceeds 40 db; closed-loop gain is between 10 and 26 db. Built-in current limiting devices make "runaway" impossible. Short circuiting the output or reversing the power supply cannot damage the unit. Price is $89.—Taber Instrument Corp., North Tonawanda, N. Y.

Circle No. 314 on reply card

ACCESSORIES & MATERIALS

HOT SPOTS

The Button-Heater shown above is only ¾ in. in diam and 0.15 in. thick,



Continuous operation— a Teletype equipment tradition

All Teletype equipment . . . like the tape punches being final-tested above . . . are subjected to a rigorous quality-control program to insure that the units will give continuous, day-in, day-out performance in your service. Such performance is a Teletype tradition, established during more than fifty years of manufacturing data communications equipment.

To maintain this performance tradition requires much more than testing, however rigorous. It begins with the very design of the units themselves—the product of extensive research and development facilities, backed by cumulative experience. And it involves precision manufacture—employing the latest technological advances, from highly specialized machine tools and automated processes to electronic measuring and sensing devices.

When you select Teletype equipment to speed your communications and cut your paperwork costs, you can be sure of built-in quality. Teletype Corporation manufactures this equipment for the Bell System and others who require the utmost reliability from their data communications systems.

Typing Tape Punch

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CIRCLE 179 ON READER SERVICE CARD

DESIGN NOTES on

Control by Rotary Switches

(No. 1 of a series)

The multi-pole, multi-circuit, rotary switch is one of the most versatile devices for control of electric circuits yet it is not as widely used as it should be, because many designers are not familiar with its construction and application.

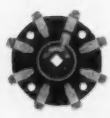
In these Design Notes, the operating principle and the structural features of rotary switches will be discussed in relation to a wide variety of controls — some simple, some complex, some light-duty, some heavy-duty, and some that defy classification.

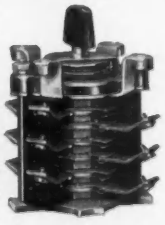
Exploded view of ESCO Type JR – a typical rotary switch.

The type of switch we are talking about does not fit into any clearly defined category. It is called a *rotary switch* because its moving parts rotate on a shaft so that the switch can be operated by turning a knob, handle, or hand-wheel — either manually or by a motor, solenoid, or other form of power drive. Altho the term *rotary switch* is sometimes loosely used to mean any switch that can be operated by turning a shaft (as in the case of a switch having cams that open and close contact circuits), there are important differences that put the true rotary switch in a class by itself for many applications.

Basic Structure of Rotary Switch

The first characteristic to be considered is the physical arrangement of the contacts. In the rotary switch, stationary contacts are distributed radially on an insulating base, generally called a *deck*, or a *section*. Sometimes they are riveted or otherwise secured to the deck but more often they are set in molded recesses. The movable contacts, which are carried on an insulating member keyed to the switch shaft, are free to move slightly so as to align themselves with the stationary contacts. Since the shaft is generally made of metal, insulation adequate to prevent flashover is provided between the movable contacts and the shaft. In some designs, the movable contacts are connected to the external circuit through a slip ring; such switches are generally called tap, or selector switches. For more complex circuit controls, the movable contacts may be used to interconnect two or more stationary terminals.





NEW PRODUCTS

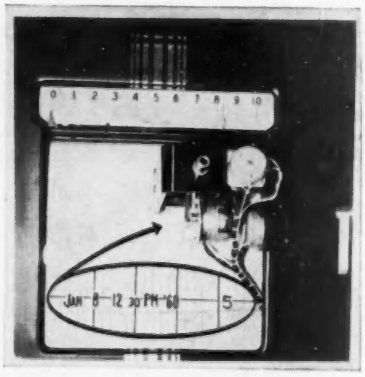
yet ratings of 2, 5, or 10 watts are available. Heater internal temperatures to 500 deg F are permissible. Two 6-in. No. 28 Teflon insulated lead wires are provided; a center hole allows screw mounting directly to the piece to be heated. One or two units are $10 a piece; quantities of three through 10 are $8.50 each.–Minco Products, Inc., Minneapolis, Minn.

Circle No. 315 on reply card

SIMPLIFIES ASSEMBLY

Several composites of silver or noble metal solder alloys clad to base or precious metals are now available in sheet, strip, and foil. Use of these composites eliminates separate fabrication of solder pieces and the need for many cleaning and fluxing operations. Sheets are available (except for stainless steel composites) to as thick as 0.500 in. in 20-in. widths.–General Plate Products, Texas Instruments, Inc., Metals & Controls Div., Attleboro, Mass.

Circle No. 316 on reply card



PRINTS ON THE CHART

A new accessory for strip chart recorders, the Identichart RI-5 automatically prints date, time (to the nearest minute), and one of twelve remotely selected code symbols. It eliminates much of the manual marking needed to pinpoint the time or sequence of condition changes. Unit is supplied in an easy-to-install kit form. Its time clock operates on 60-cycle ac voltage, the printing mechanism on any ac or dc source from 24 to 115 volts.–Royson Engineering Co., Hatboro, Pa.

Circle No. 317 on reply card

TAKE A GIANT STEP

. . . into your future and seek out the professional opportunities awaiting creative engineers and scientists at Martin-Denver . . . For here exists the most challenging problems in space and human engineering. Join with us and communicate with N. M. Pagan, Director of Technical and Scientific Staffing (Dept. 1C), The Martin Company, P. O. Box 179, Denver 1, Colorado.

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TubeXperience in Action

Deep well pressure readings within .05% accuracy with help of Superior Ni-Span C* Bourdon Tubing

Accurate down-well pressure readings, indicating changes of only 1 to 4 psi at bottom-hole pressure of 2000 psi, are hard to get, but extremely important. They demand a pressure gage accuracy of at least 0.1% to make the vital engineering calculations based on them of any value.

To achieve this accuracy and better it, Superior was asked for help in selecting the Bourdon tube material for an improved bottom-hole measuring device. After careful study, its metallurgists recommended Ni-Span C nickel-chrome alloy for the Bourdon tubes. This material was chosen for its relative insensitivity to temperature changes, coupled with superiority in operating temperature, mechanical hysteresis, and elastic drift; also for its fatigue resistance and spring properties.

The customer followed the suggestion and now this gage, which is unique in bottom-hole pressure instruments for the reason that it utilizes a helix-wound Bourdon tube to transmit directly the effects of pressure to a recording stylus, is rated 0.1% accurate. In fact, with special care in operations and calibration, it can measure within .05% accuracy.

NI-SPAN C TUBING NOW STANDARD AT SUPERIOR

Ni-Span C redraw stock is now in inventory at Superior, available for immediate production in a range of sizes from .010 in. to ⅜ in. OD, up to .125 in. wall max., and from ⅝ in. to 1⅛ in. OD in wall thicknesses up to .035 in. max. Shaped tubing can be produced to customers' prints. Perhaps you have an application that can benefit from its unusual properties. Write for Data Memorandum No. 19. Superior Tube Company, 2026 Germantown Ave., Norristown, Pa.

**Registered trademark of International Nickel Co.*

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

All analyses .010 in. to ⅜ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

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IMPORTANT: Circle key numbers below and mail before August 1, 1960

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2	12	22	32	42	52	62	72	82	92	102	112	122	132	142	152	162	172	182	192
3	13	23	33	43	53	63	73	83	93	103	113	123	133	143	153	163	173	183	193
4	14	24	34	44	54	64	74	84	94	104	114	124	134	144	154	164	174	184	194
5	15	25	35	45	55	65	75	85	95	105	115	125	135	145	155	165	175	185	195
6	16	26	36	46	56	66	76	86	96	106	116	126	136	146	156	166	176	186	196
7	17	27	37	47	57	67	77	87	97	107	117	127	137	147	157	167	177	187	197
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206	216	226	236	246	256	266	276	286	296	306	316	326	336	346	356	366	376	386	396
207	217	227	237	247	257	267	277	287	297	307	317	327	337	347	357	367	377	387	397
208	218	228	238	248	258	268	278	288	298	308	318	328	338	348	358	368	378	388	398
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4	14	24	34	44	54	64	74	84	94	104	114	124	134	144	154	164	174	184	194
5	15	25	35	45	55	65	75	85	95	105	115	125	135	145	155	165	175	185	195
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8	18	28	38	48	58	68	78	88	98	108	118	128	138	148	158	168	178	188	198
9	19	29	39	49	59	69	79	89	99	109	119	129	139	149	159	169	179	189	199
200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390
201	211	221	231	241	251	261	271	281	291	301	311	321	331	341	351	361	371	381	391
202	212	222	232	242	252	262	272	282	292	302	312	322	332	342	352	362	372	382	392
203	213	223	233	243	253	263	273	283	293	303	313	323	333	343	353	363	373	383	393
204	214	224	234	244	254	264	274	284	294	304	314	324	334	344	354	364	374	384	394
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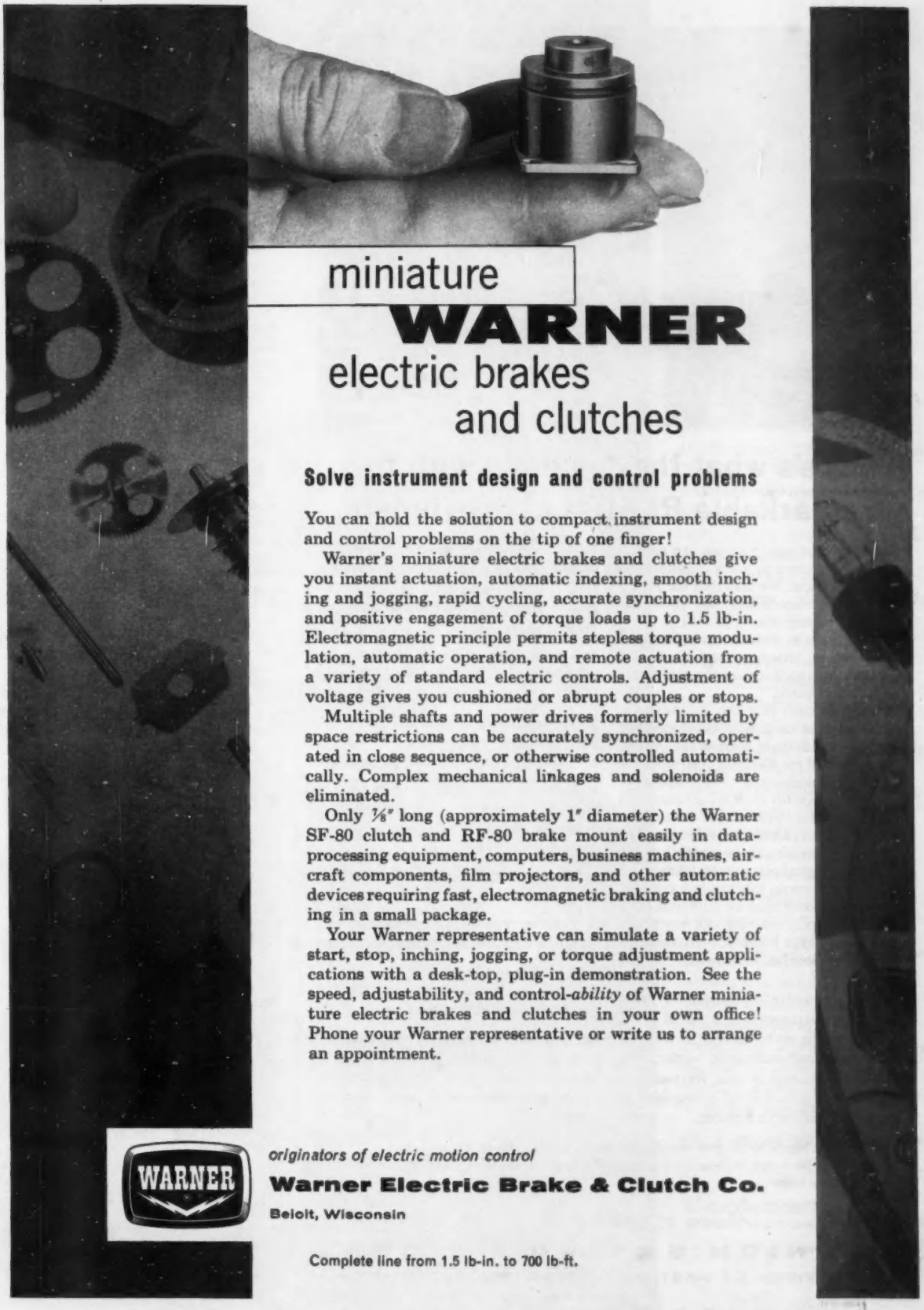

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BULLETINS AND CATALOGS

NOTE: This month's Bulletins and Catalogs section starts with several items for which written requests are necessary. Complete addresses are given for these. For any other item, circle appropriate number on the reader reply card.

THERMISTOR DATA. Victory Engineering Corp., 512 Springfield Rd., Union, N. J. Available at $1.00 per copy, this revised VECO data book has been designed to provide engineers, purchasing agents, sales personnel, and management sufficient information to enable them to evaluate the needs in their own activities for thermistors, Varistors, and allied devices. Thermistor data includes operating characteristics, temperature-resistance curves, voltage-current curves, current-time curves, and some typical applications. A three-page bibliography lists almost every important paper on thermistors and Varistors written within the last 20 years.

400 POWER SUPPLIES. Sorensen & Co., South Norwalk, Conn. This new 32-page power supply handbook and catalog provides tabular specification data on more than 400 separate power supply models. Available without a charge, it covers the complete Sorensen line of regulated dc supplies, frequency changers, high voltage power supplies, and other high voltage products; miniaturized transistorized power supplies, inverters, and converters; and ac line voltage regulators. Booklet also included extensive technical data on the selection and application of these products.

MASTER STANDARDS. PIC Design Corp., Sub. of Benrus Watch Co., Inc., 477 Atlantic Ave., East Rockaway, N. Y. Available only to department heads such as chief engineers, chief draftsmen, standards engineers, etc., it is a new master standards loose leaf manual designed to simplify the specification, modification, and inspection problems peculiar to the purchase and use of electromechanical components. Master standards are produced on reproducible tracing paper measuring 8½ x 11 in. Leather ring binder contains over 400 loose leaf pages. Manuals will be distributed personally by PIC sales engineers.

RATE GYRO DATA. Sanders Associates, Inc., 95 Canal St., Nashua, N. H., Attn: Product Mgr., Subminiature Rate Gyros. Priced at $2.00, a new 62-page "Technical Manual For Subminiature Rate Gyroscopes" opens with a detailed description of basic operating principles, then goes on to cover performance characteristics, standard types available, transformer pick-offs, and use and design of gyro packages for rate and acceleration applications. A 20-page appendix to the manual discusses factors affecting gyro performance, gives sample specification to aid the engineer, and includes a complete glossary of gyro technology.

(350) ELECTRONIC MULTIPLIER. GPS Instrument Co., Inc. Bulletin MU-500 E, 4 pp. Reviews the theory of operation and performance capability of a new electronic multiplier-divider, developed for use with the company's compressed-time-scale analog computer, but

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suitable for use as a general purpose device in the fields of reel data reduction and slow-time computation.

(351) CORROSION RESISTANCE GUIDE. Hydromatics, Inc. Charts, 6 pp. Lists the relative ability of metals, plastics, and synthetic rubbers used in the manufacture of Flo-Seal valves to resist the corrosive effects of 390 different fluids encountered in a wide range of industrial applications. Introduction shows a cross section of a typical Flo-Seal valve and the complete chemical composition and physical characteristics of materials used in its construction.

(352) DIAPHRAGM SEALS. Brooks Rotameter Co. Catalog, 24 pp. Consists of a four-page bulletin, design specification sheets, and price lists covering the Brookseal line of diaphragm seals, elements designed to protect pressure instruments against corrosion and clogging.

(353) DIGITAL INSTRUMENTATION. Cubic Corp. Bulletin 100-D, 6 pp. Covers some of the more important specifications and design features of a variety of digital instruments, including dc voltmeters, control units, preamplifiers, ac converters, scanning systems, printer control units, and the Cubic talking meter. Prices are included in some of these specifications.

(354) RELIABLE RELAYS. Magnecraft Electric Co. Catalog 160, 24 pp. Loaded with illustrations, specifications, and dimensional drawings, this bulletin covers a complete line of telephone-type relays—medium size, small, miniature, and subminiature—with a wide range of contact combinations including bifurcated, heavy duty, and power contacts. Special features include a coil data chart and a listing of relay contact code numbers.

(355) FAN AND BLOWER SELECTOR. Globe Industries. Inc. Bulletin FB, 4 pp. Serves as a simplified guide to determining cooling requirements of electronic apparatus and shows how to select the proper type and capability of miniature fans and blowers.

(356) DATA SYSTEMS. Southwestern Industrial Electronics Co. Illustrated bulletin describes the SIE MS-12 GeoData geophysical data processing system, a package designed to handle both SIE FM and direct recorded AM magnetic tapes to produce a pen recorded time cross section on paper which can be photographically reproduced.

(357) FLUID POWER PRODUCTS. Flick-Reedy Corp. Bulletin P2547P, 24 pp. Sectionalized by products, this two-color bulletin covers air cylinders, hydraulic cylinders, nonsag piston rods, high speed cushions, adjustable stroke cylinders, air hydraulic boosters, air-oil circuits, and Tru-Seal pipe thread fittings for eliminating positioning problems and leakage.

(358) CONVERTER DESIGN. Magnetics, Inc. Design report, 16 pp. Outlines new approaches to the design of compact, inexpensive, and versatile dc-to-dc and dc-to-ac converters. Introductory section presents data on converter design factors, transistor selection, and magnetic core characteristics. Second half contains complete step-by-step information

on two theoretical case histories: design of a power converter and design of a dc-to-dc high voltage supply.

(359) THERMAL INSULATION. Monsanto Chemical Co. New technical bulletin describes the chemical, physical, and structural properties of Santocel A, a silica aerogel used for thermal insulation. Suggests a number of typical applications.

(360) VALVE BOOKLET. United Aircraft Products, Inc. Booklet 5911251, 8 pp. Introduction details design and selection factors such as function, application, and method of actuation. Subsequent pages provide engineering data, characteristics, range specifications, and illustrations of various types of valves: bypass, relief check, regulator, etc.

(361) SUPERVISORY CONTROLS. ASCOP Div. of Electro-Mechanical Research, Inc. Brochure SC 3M020, 12 pp. Describes an advanced supervisory control system that has found wide application in pipe line transmission systems, unattended electric utility substations, microwave relay stations, and similar applications. Also shows detailed operating sequences for the various types of control and supervision which can be specified.

(362) RAPID TRANSLATION. Electronic Engineering Co. Applications information manual, 16 pp. Second edition of this handy manual covers the data translation capabilities, basic translation system, common translation modes, and other basic information on the company's Model ZA-100 computer range translator. Illustrated appendix outlines the CLT systems now in operation in various parts of the United States.

(363) SERVOMOTOR CATALOG. Helipot Div., Beckman Instruments, Inc. Size 18 catalog, 16 pp. Complete with typical unit characteristics, specifications, dimension drawings, and torque-speed curves, this two-color catalog covers the company's full line of Size 18 servomotors and servomotor-rate generators. Includes specification check list for use when other than standard units are required.

(364) CONTROLLED SPEED SYSTEMS. U. S. Electrical Motors, Inc. Color brochure, 8 pp. Amply illustrated with schematic drawings and application photographs, brochure briefly explains the U. S. Varidyne controlled speed system principle and shows how it has been applied in multimotor installations.

(365) CONVERSION FACTORS. Precision Equipment Co. Wall chart. A handy reference for engineers and technicians, this new conversion factor wall chart lists most of the common conversions such as inches to centimeters or watts to horsepower as well as many conversions that are difficult to locate in reference manuals. Some examples of the latter include atmospheres to kilograms per square centimeter, centimeter per second to mph, cubic feet to liters, microns to meters, etc.

(366) PROXIMITY METER. Aeronautical & Instrument Div., Robertshaw-Fulton Controls Co. Technical and application manual TM-951-2, 28 pp. Contains a complete technical description of a new capacitance operated proximity meter, including circuit and differential information. Applications outlined include use of

Bulletins & Catalogs

the instrument as a micrometer, concentricity gage, surface gage, strain gage, pressure gage, and vibration meter. Manual also lists performance specifications and control adjustments.

(367) UNVAC APPLICATION. Remington Rand Div., Sperry Rand Corp. Bulletin U1715, 4 pp. One of a series of 60-sec management interviews, this illustrated two-color bulletin tells how a large New York savings and loan association has improved its entire customer service operation with a new Univac 60 computer.

(368) PRECISION DRIVE MOTORS. Rodine Electric Co. The Rodine Motorgram, Vol. 40, No. 1. 4 pp. Feature two articles on typical applications of the company's split-phase synchronous motors. Third article discusses the techniques for controlling the speed of various fractional horsepower motors.

(369) POT SELECTOR CHART. Spectrol Electronics Corp. Wall selector chart, 24 x 30. Useful engineering aid contains complete and easily read specifications on 37 standard models of single- and multiturn precision potentiometers. Lists electronic and mechanical ratings, dimensions, environmental data, and special features.

(370) SEALED CIRCUIT BREAKERS. Airpax Electronics, Inc. Bulletin B-07, 4 pp. Describes the new Series 500 hermetically sealed electromagnetic circuit breaker, discussing such characteristics as, time delay, trip level, current ratings, frequency ratings, possible combinations, and release coil resistances. A typical time delay curve and outline dimension drawings are included.

(371) HIGH-SPEED MEMORIES. Telemeter Magnetics, Inc. Specification DF-115.1, 4 pp. Deals with a series of general purpose high speed memories designed to provide both random access and sequential types of operation. Illustrations include a block diagram and bar graphs showing typical write, read, and memory operations.

(372) SAMPLING RELAY. James Electronics, Inc. Catalog sheet F-2218, 2 pp. Provides full technical details on the company's new line of Micro-Scan relays designed for dc, asynchronous, and synchronous switching of extremely low microvolt level to moderate level signal circuits such as those found in analog and digital computers.

(373) FLOW-CONTROLLED PUMP. Milton Roy Co. Data sheet D-59-1. Application engineering data sheet explains how controlled volume pumps solved the problem of metering a softening agent by incorporating an automatic stock length adjustment that would respond to flow rate changes in the main line.

(374) MHD POWER. Missile & Space Vehicle Dept., General Electric Co. Bulletin PPIB-40, 4 pp. Outlines the work done at GE's Space Sciences Lab in magnetohydrodynamics, the study of techniques for extracting electric power directly from ionized gas as it passes through a magnetic field. Photos and line drawings illustrate the experimental hardware already developed and both open- and closed-cycle applications.

(Continued from page 48)

ishes his design he turns it over to the production department where a technician determines what connections have to be made. The technician notes every connection and orally describes it into a Dictaphone Audio Instructed Manufacturing Operations system (AIMO). A typical instruction: "connect module J-11, pin little *j* to module J-12, pin capital *F*."

At the wiring bench, the harness maker wears a headset and sits with the wire supply; the AIMO machine is connected to two foot pedals. She steps on one pedal, hears a single wiring instruction. The machine automatically stops at the end of the instruction, and another press on the pedal is required to get the next instruction. Pressing the second pedal, the operator can make the machine repeat the last instruction if she did not hear it clearly.

By placing wiring instructions on tape, Adage calculates it has cut harness wiring from six days to two. But probably an even bigger advantage has been the reduction of wiring errors.

After the wiring harness is completed, the harness, the required modules, and a cast aluminum container are all shipped to the application engineer who designed the digitizer. He has the job of putting in the modules, connecting the harness, and making the digitizer work.

• **Reorganized the company** – Adage's technique has worked so well that the company's organization was changed to conform better to the production method. Today the company has three major departments:

• Marketing Department–sells the digitizer, designs it with stickers, performs final assembly, tests, delivers, and services the finished digitizer.

• Product Department – conducts research to develop new techniques and modules with different or added functional capability.

• Manufacturing Department–builds the printed circuit boards and wires the harnesses to the marketing department's specifications.

This approach has cut average delivery times from about 100 days to 45 days. In fact, says Product Development Manager Eric Howlett, a digitizer very similar to one previously made can now be produced in seven days.

Just as important, however, is the flexibility that the technique provides, says Howlett. And it has reduced the amount of time application engineers have to haggle over production details.

Systematize For Systems

A traditional communications supplier formed a subsidiary to chase the systems business. After one year's growing pains, the subsidiary is breaking into stride, expects to sprint to sales of $100 million in three years.

DALLAS

In Richardson, Tex., (just outside Dallas) two lines of trailers resembling a trucking company terminal cluster incongruously beside a 40-ft "dish" radar antenna. Actually the test site for a transportable space probe tracking station, the system was built by Alpha Corp., a subsidiary formed by Collins Radio Corp. just a year ago.

The tracking stations contract represents $6¼ million of the current $50 million worth of contracts that Alpha has in the house at present. That's the same dollar volume on hand when Collins started the unit last April, but Alpha President Max W. Burrell expects sales to reach $100 million in three years.

The original backlog came from Collins, of course, which started Alpha as a bid to step into the systems engineering and management business. But Burrell believes Alpha will be able to get more and more of its business on its own in the future.

• **Not a manufacturer**—The plan from the beginning was for Alpha to concentrate entirely on systems management and engineering, leaving Collins to be strictly a manufacturer. Burrell believes his some 700 engineers, technicians, and supporting personnel are now trained to think systems, but putting this across has been one of his big problems.

"We have been a year trying to teach our people that we aren't in the manufacturing business," he says. "They have had to unlearn what they had been doing for Collins. This has been difficult, and we have had to bring in a dozen top engineering administrative people with experience in installing systems."

Burrell's ideas of how an organization like Alpha should be set up have caused some readjustment pains, too. He determined to set up a system that would get work done right, on

time and at minimum cost.

• **Completely in charge**—He divided the fledging group into six divisions and put each division under a vice-president and project executive. Each of the division heads has a complete project management, engineering, and administrative group capable of handling a contract. He's held accountable for showing a profit on a project and for completing it on time.

Prime contracts underway in addition to the satellite tracker (which is for the Signal Corps and ARPA) include an integrated fleet communications systems for the Navy, ground based surveillance systems, telecommunications and command-destruct systems for major missile ranges, and construction contracts for primary manufacturing, research, and operating facilities in the U. S. and abroad.

• **Systems in the factory**—Burrell hopes to see Alpha do a bigger selling job in the future on planning the entire layout of all machinery and electronic equipment that might be required for a plant—before the installation is put up.

He's also interested in the company going after more nonmilitary work. Currently 80 percent of Alpha's business is in defense orders. Burrell thinks 50-50 is a good defense—commercial balance.

An example of some meaty commercial business is a study Alpha's done for an "exotic" microwave system for a proposed 1,500-mile gas transmission line. Petroleos Mexicanos (Pemex), Mexico's nationalized oil industry, has asked for studies that may lead to more pipeline microwave contracts, and a foreign railroad has asked for some automation studies.

—Marvin Reid
McGraw-Hill News

Analog satellite tracking data is converted to digital form for teletype transmission in one of the vans of Alpha Corp.'s transportable tracking station.

WHAT'S NEW

DuMont Labs Finds a Buyer: Fairchild Camera

Arrangements have been started to finalize the proposed merger of Allen B. DuMont Laboratories into Fairchild Camera & Instrument Corp. in a stock exchange transaction.

Fairchild, the surviving company, had been negotiating with the Clifton, N. J., firm for two months before the deal was first announced. This means the talks were going on when Republic Aviation Corp. was considering buying DuMont. Republic dropped the idea.

Fairchild has also been active with other companies: last October an unsuccessful bid was made to merge with R. C. Allen Business Machines, Inc. Along with DuMont's military and industrial electronics business (it no longer makes TV sets), the Syosset, N. Y., company gets a tax loss carry forward of about $10 million.

TRWP, Republic Team Up For Utility Control

Republic Flow Meters Co. and Thompson-Ramo-Wooldridge Products will cooperate in designing and furnishing computer control systems for the electric power industry.

Republic (a subsidiary of Rockwell Manufacturing Co. located in Chicago) will combine its experience in electronic control and valving systems for steam boilers with TRWP's know-how in computing-control.

► Another process instrument company-computer maker tie-up was announced by **Bailey Meter Co.**, Cleveland, which will apply Packard-Bell Computer Corp's GP computer (see p. 32) as a component of control systems.

News of Other Companies In the Control Field

Systron Corp. has acquired Donner Scientific Co. to be a subsidiary of Systron-Donner; they're next-door neighbors in Concord, Calif.

Avien, Inc., Woodside, N. Y., will exchange stock to acquire Colvin Labs, Inc. and Pressure Elements, Inc., both of E. Orange, N. J.

General Mills, Minneapolis, Minn., has been negotiating to acquire The Daven Co. and Laible Manufacturing Co., Livingston, N. J., and Manchetser, N. H.

Control Data Corp. and **Control Corp.**, both of Minneapolis, Minn., have obtained stockholder approval of an arrangement whereby the latter firm will become a subsidiary of Control Data.

Atlee Corp., Woburn, Mass., has merged Industrial Electronics Co., Inc. and Applied Dynamics Corp., neighbor companies in the Boston area. All three will trade under the Atlee name. The Applied Dynamics Corp. shouldn't be confused with Applied Dynamics, *Inc.*, recently purchased by Bowmar Instrument Corp. (CtE, April '60, p. 204).

RCA, which has up till now bought all its magnetic tape for producing records and for prerecorded and blank sales, will now produce it for professional, broadcasting, industrial, and home use at a new Indianapolis plant.

Borg-Warner Corp., Chicago, has stepped more firmly into the field with a new Borg-Warner Controls Corp. formed out of the facilities of BJ Electroincs, a B-W property.

McDonnell Aircraft Corp., St. Louis, has announced the establishment of a new division to offer complete electronic data processing services.

IMPORTANT MOVES BY KEY PEOPLE

Dr. Batdorf Heads Planning At Ford's Aeronutronic

Manager of product planning for Range Systems Operations of Aeronutronic, a division of Ford Motor Co., is Dr. Samuel B. Batdorf. He comes to the Newport Beach, Calif., company after serving as director of research for Lockheed Electronics Co.'s Newport Div. (formerly Lockheed Electronics and Avionics Div.).

Dr. Batdorf joined Lockheed in 1956 at its Missile Systems Div. and was assistant director of research and head of the Electronic Div. He was also technical director of Lockheed's satellite projects (Midas, Samos, and Discoverer).

In 1958 he took a leave of absence to help plan the military space program for the Advanced Research Projects Agency, where he initially headed the Man-In-Space Project.

Gen. Gavin Becomes A. D. Little President

Lt. Gen. James M. Gavin (USA Ret.) has been elected president of Arthur D. Little, Inc., Cambridge

WHAT'S NEW

(Mass.) industrial research firm. He succeeds Raymond Stevens who retired as the company's head.

Gen. Gavin joined A. D. Little in 1958 after serving as chief of Army Research and Development. He spent 30 years in Army service. Last March he was promoted to executive vice-president of the Little concern.

Nichinson New President At Kollsman Instrument Corp.

David B. Nichinson took over as president of Kollsman Instrument Corp. last month, replacing Victor E. Carbonara who has retired. With Kollsman for 15 years, Nichinson was previously on the staff of MIT's Radiation Lab. The New York firm is a subsidiary of Standard Coil Products Co., Inc.

Other Important Moves

Dr. Geza S. Gedeon is the new head and research scientist of the Astrodynamics Laboratory, a unit of the Astro Systems and Research Labs at Northrup Corp.'s Norair Div., Hawthorne, Calif. Dr. Gedeon was a senior scientist at Ford's Aeronutronic Div. and at Chance Vought Aircraft's Research Center.

Dr. Morton B. Prince has become vice-president and general manager of the Semiconductor Div. of Hoffman Electronics Corp. He succeeds Maurice E. Paradise, now corporate vice-president for product planning of the Los Angeles firm.

Benjamin H. Ciscel has been appointed general manager of the Vought Electronics Div. of Chance Vought Aircraft, Inc., Dallas, Tex.

Solomon Charp is now the manager of navigation and control electronic equipment for GE's Missile and Space Vehicle Dept. in Philadelphia. The operation he heads is newly organized to meet increased demands for components for guidance and control of space vehicles.

Arnold F. Kaulakis has been named acting general manager of engineering at the Esso Research and Engineering Co., Linden, N. J. In this post he will be responsible for the 800-man engineering support force for the world-wide petroleum refining and petrochemical operations of Standard Oil Co. (N. J.).

ABSTRACTS

Steel process control

From "End-Point Temperature Control of the Basic Oxygen Furnace", by W. J. Slatosky, Jones & Laughlin Steel Corp. Paper presented at a meeting of the American Institute of Metallurgical Engineers, 1960.

To effect better control of end-point temperatures at the J & L basic oxygen furnace plant, a set of mathematical equations has been developed which facilitates the computation of thermally balanced charges. The equations, given in the appendices, are the product of thermochemical analysis of the process and are designed to calculate the required scrap, lime, and hot metal additions in terms of a number of independent variables.

Having formulated the mathematical model relating process variables to the finishing temperature, a special slide rule was developed (described and illustrated in the paper) to solve the end-point temperature equation. During a trial period, 249 of 323 calculated heats agreed to within plus or minus 20 deg F (at a nominal finishing temperature of 2,900 deg F), and 297 were within 30 deg F of the measured values. From these results it was concluded the model was mathematically sound.

During another trial period from April 6 to May 9, 1959, 227 of the heats produced were charged with additions calculated from the mathematical model using the slide rule. A total of 148 of the 227 test heats, or 65.1 percent, were within the permitted temperature range at the completion of the heat. As a comparison, a composite of all the other heats made without the aid of the mathematical model during the time of the trials showed that only 48.3 percent of the heats were within allowable range. In addition to the 16.8 percent improvement over the composite performance, the heats computed with the slide rule are normally distributed, whereas the other heats yield a skewed distribution.

Numerous reasons can be advanced to explain the occurrence of off-temperature heats even when using the slide rule. Among these are error in the mathematical model, erroneous iron temperature measurements caused by smoke interfering with the two-color pyrometer, long delays, error in weighing additions, and computational errors. Some of these error

ABSTRACTS

sources are being corrected.

In particular, it was decided that an electronic computer rather than the special slide rule would be better suited for use by operations personnel because of its greater accuracy and ease of operation. The computer is on order and will be installed in a few months. It is expected that the reduced number of off-temperature heats will be accompanied by significant financial returns.

Researching computers

From "Research on Automatic Computation Techniques and Components", by W. M. Becker, R. W. Clark, and M. S. Hall, National Cash Register Co. for Wright Air Development Center, U.S. Air Force, Dec. 1958. Now available from Office of Technical Services, U.S. Dept. of Commerce, Washington 25, D.C. as PB 151834, 176 pp., $3.

This research was accomplished in three phases. The first was an engineering study of the implementation of a notation scheme to serve as the arithmetic unit of a digital computer. Ways were found for operating magnetic core function matrices faster and more reliably and for operating large magnetic core matrices at high speeds without redundant circuitry. In the second phase, processing methods were sought through study of barium titanate films which might lead to ferroelectric behavior suitable for use in computer devices. Phosphor-photoconductor research, the third phase, was aimed at making a fast electrooptical switch for logic circuitry in digital data processing systems by using the best combination of polycrystalline electroluminescent (EL) and photoconductive (PC) materials. Cadmium sulphide PC materials provided the most promising approach to functional EL-PC switches, but the minimum switching time was 1 millisec.

Control symbols

From "International Federation of Automatic Control Information Bulletin 6", by E. Gerecke in cooperation with J. F. Coales and V. Broida. Copies available from the Secretary of IFAC, 79 Prinz-Georg-Str., Dusseldorf, Germany.

The penetration of automatic control techniques in varous engineering fields emphasized the lack of, and need for, graphical symbols for con-

trol which could be applied to all fields of engineering. To expedite the international acceptance of graphical symbols useful for control engineering, IFAC has published and invites criticism of the information bulletin containing the graphical symbols proposed by Prof. Gerecke.

The bulletin details several categories of symbols: signals and quantities transferred; mathematical combinations of signals including algebraic and logic operations; linear and nonlinear transfer elements; amplifiers and transmitters; storage elements; and measuring and recording devices, final control elements, and control units.

The symbols are presented in tabular form along with a written description or designation. Frequently an alternate symbol is listed. The basic presentation is in English, but the bulletin also contains translation of terms into French and German.

Calibrating rotameters

From "The Calculation of the Suspended-Body Flowmeter", by K. Lutz. Regelungstechnik, October 1959, pp. 355-360. In German.

The formulas for calculating the characteristics of a variable area flowmeter are derived from the linear and quadratic resistance laws for bodies placed in a fluid. A table of calibration factors permits the transformation of one formula into the other. This empirically established table of calibration factors represents the whole field of characteristics of a variable area flowmeter. It gives information on the behavior of the flowmeter, in particular with regard to properties of the fluid like density and viscosity.

The calibration scale for any fluid can be calculated from the derived formulas and from the calibration factors, if the dimensions of the particular flowmeter are known. So empirical calibration is no longer needed.

Briefly noted

From "Design of Single Frequency Filters", by F. F. Fulton, Jr., National Bureau of Standards Technical Note 23, Aug. 1959. Available from Office of Technical Services, U.S. Dept. of Commerce, Washington 25, D.C., as PB 151382, 10 pp., $0.50.

Design procedures are shown for filters formed by a number of identical resonant circuits loosely coupled together. They are required to accept one narrow band of frequencies and reject another narrow band somewhat removed in frequency, without special shape requirements on the attenuation curve between these designs.

NEW BOOKS

RUSSIAN BOOKS

The following brief reviews of a number of recent Russian technical books are presented for two reasons. First, these books may be a source of learning for some CONTROL ENGINEERING *readers, despite the language barrier. Copies of all of the books listed are available from the Library of Congress. In addition, the reviews should provide some insight to the state of the control art in Russia. Of particular interest is the number of copies of each book published, a figure indicative of the size of the field and the relative importance given the subject.*

PRINCIPLES OF THEORY, DESIGN AND CALCULATION. *F. A. Stupel,* 1956. 354 *pp.* 20,000 *copies printed.*

The author discusses the fundamentals of the theory and design of relays and contact mechanisms based on various principles of operation, i.e., electromagnetic, induction, etc. He also considers problems in the design of coils, contact systems, springs, and supports. There are 39 references, all Russian.

ADJUSTMENT OF AUTOMATIC CONTROLLERS IN THE METALLURGICAL INDUSTRY. *P. G. Baranovskiy,* 1959. 123 *pp.* 4,000 *copies printed.*

The author presents the basic theory of automatic control and describes types and characteristics of systems and elements for the automatic control of thermal processes. Problems in adjusting thermal control systems and some distinguishing features of the physical processes of automatic control in metal-cutting plants are discussed. Types of test benches and methods of testing and adjusting controllers are described. There are 10 references, all Russian.

MATHEMATICAL METHODS OF INVESTIGATION OF AUTOMATIC CONTROL SYSTEMS. *V. I. Zubov,* 1959. 323 *pp.* 6,500 *copies printed.*

In the book a study is made of the mathematical methods of studying the stability of steady state motions in nonstationary systems, and an evaluation of the deviations of transient processes from steady state motions is given. Methods are presented for constructing the solutions of certain systems of differential equations, to which a wide class of automatic control systems is reduced. Certain methods of finding the probability characteristics of stochastic transient processes are de-

scribed as well as methods of finding stability regions in the space of initial data and in the space of allowable values of the parameters.

FUNDAMENTALS OF THE THEORY OF AUTOMATIC CONTROL SYSTEMS USING RADIOACTIVE ISOTOPES. *N. N. Shumilovskiy*, 1959. 141 *pp.* 5,000 *copies printed.*

The book sets forth the theory, evaluation methods, and principal schematic diagrams of automatic control systems based on the utilization of nuclear radiation. The following topics are covered: use of radioactive isotopes in instrument design and level measurement, methods of increasing the accuracy of radiation intensity measurement and thickness measurement, automatic flaw detection with gamma rays and dynamic compensation, apparatus employing alpha radiation, methods of density measurement, relay control methods, and backward scattering of beta radiation.

COMPUTATION TECHNIQUE AND ITS APPLICATION. *S. A. Lebedev et al.*, 1959. 391 *pp.* 5,000 *copies printed.*

The authors present fundamentals of digital computers and their subsystems like arithmetic units, internal and external memories, and control devices. They discuss the possibility of constructing computers using semiconductor elements and consider the fundamentals in the theory of logical circuits. Also covered are problems of programming, and explanations of the operation of analog computers and their elements are given. Brief discussion of mathematical instruments is also presented.

AUTOMATION OF PRODUCTION, 1959. 31 *pp.* 47,500 *copies printed.*

The three articles comprising this pamphlet discuss the status of automation in machinery-manufacturing operations, review the prospects for automation of the chemical industry, and briefly describe computing devices necessary for automating production processes.

USE OF ELECTRONIC ANALOG COMPUTERS IN THE ANALYSIS OF AUTOMATIC CONTROL SYSTEMS. *B. Y. Kogan*, 1959. 492 *pp.* 10,000 *copies printed.*

The contents of this book are confined to a detailed study of dc electronic analog computers and their basic computing elements and to

NEW BOOKS

problems of applying analog computers to dynamic automatic control systems. The book is based on the assumption that the operational amplifier has idealized frequency characteristics; i.e., its transfer function in the open-loop state is a constant number equal to the amplification coefficient. The book makes use of the results of a number of electronic analog computers of the EMU type, developed by the author and his colleagues at the Institute of Automation and Telemechanics.

ELECTRIC ANALOGING. *I. M. Tetelbaum*, 1959. 319 pp. 10,000 *copies printed.*

This book explains the fundamental ideas underlying the construction of electrical analog devices and the principles of their application. In the first part the general characteristics of analoging methods are given, and a study is made of similitude problems and analoging precision. The second part is devoted to the analoging of physical systems, that is to problems on the solution of ordinary differential equations by means of direct analogs, structural and matrix models. In the third part a study is made of the solution of boundary value problems on models in the form of electrically conducting media and electric grids. There are 26 Russian and one English reference.

SYNTHESIS OF STRUCTURES OF HIGH-PRECISION AUTOMATIC CONTROL SYSTEMS. *M. V. Meyerov*, 1959. 284 *pp.* 10,000 *copies printed.*

This book deals with the synthesis of precision automatic control systems. It is claimed to be the first book to systematically present material on the synthesis of structures of automatic control systems. The term structure as used in the book refers to the dynamic properties of systems and their component elements, as described by their transfer functions. Thus, physically different systems (electric, hydraulic, etc.) can have the same structure. Problems of stability are dealt with, and an attempt is made to establish scientific principles for the design of systems stable at any value of gain. A discussion of the behavior of several automatic control systems with accompanying equations and diagrams is presented. General procedures for solving typical automatic control problems are outlined. Other related problems are also discussed. Examples of the material discussed in each chapter are given. There are 49 references: 42 Russian, and seven English.

NEW BOOKS

Writer's Guide

A TECHNICAL WRITER'S HANDBOOK. *Margaret Norgaard.* 241 pp. *Published by Harper & Bros., New York.* $3.75.

Technically trained people often have trouble when they must turn writer to produce reports, proposals, articles, or even speeches. While this new handbook cannot be recommended as a one-volume bible for the technical writer, it presents some features that should make it a useful addition to an author's bookshelf. Used with a good dictionary and copies of the more classic writer's companions (the author lists suggested reference books in an appendix), the book gives aid in the areas that plague particularly the technical writer.

The author, a technical editor for Remington Rand-Univac, gives her philosophy of writing and some guides to how go about it. Her rules for grammar, punctuation, abbreviations, etc. are made more valuable by their reflection of up-to-date practice. Especially useful is the attention to the problems in technical literature involving hyphens, abbreviations, etc.

MEETINGS

MAY

Institute of Radio Engineers, 12th Annual National Aeronautical Electronics Conference, Dayton, Ohio May 2-4

Instrument Society of America, Sixth National Flight Test Instrumentation Symposium, Hotel Del Coronado, San Diego, Calif. May 2-5

Western Joint Computer Conference, sponsored by IRE, AIEE, ACM, Jack Tar Hotel, San Francisco, Calif. May 3-5

National Association of Relay Manufacturers, Eighth Annual Conference, Oklahoma State University, Stillwater, Okla. May 3-5

Instrument Society of America, Third National Power Instrumentation Symposium, San Francisco State College, San Francisco, Calif. May 9-11

Instrument Society of America, Instrument-Automation Conference and Exhibit, Civic Auditorium and Brooks Hall, San Francisco, Calif. May 9-12

Amercian Society for Metals, Second Southwestern Metal Congress and Exposition, Sheraton Dallas Hotel, Dallas, Tex. May 9-13

Electronic Components Symposium, sponsored by IRE, AIEE, EIA, WEMA, Washington, D. C. May 10-12

American Material Handling Society, Third Western Regional Material Handling Show and Packaging Cavalcade, Great Western Exhibit Center, Los Angeles, Calif. May 11-13

Superconductive Techniques for Computing Systems Symposium, sponsored by Office of Naval Research (Information Systems Branch), Dept. of Interior Auditorium, Washington, D. C. May 17-18

American Society of Mechanical Engineers, Production Engineering Conference, Hotel Schroeder, Milwaukee, Wis. May 17-19

American Society of Mechanical Engineers, Oil and Gas Power Conference and Exhibit, Muehlebach Hotel, Kansas City, Mo. May 22-26

Ninth National Telemetering Conference, Miramar Hotel, Santa Barbara, Calif. May 23-25

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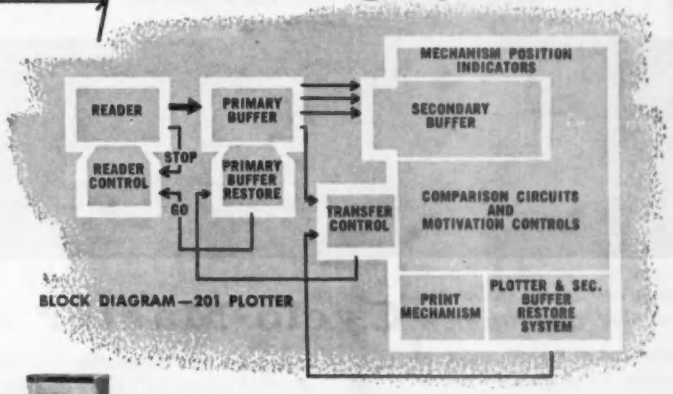

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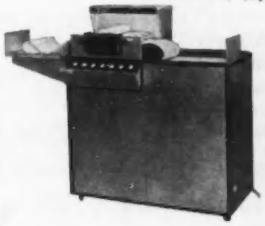

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McGRAW-HILL BOOK NEWS

MOTOR SELECTION AND APPLICATION

Just Published—Clearly and simply presents information necessary to determine the proper application of electrical motors for industrial service. Describes motor selection in terms of load characteristics; service requirements; space limitations; and safety and duty cycle requirements. Charts, tables and illustrations relate these load variables to specific motor characteristics. **By Charles C. Libby, Fairbanks, Morse & Co. 480 pp., 220 illus., $13.50**

SERVOMECHANISM PRACTICE

Just Published—A practical approach to handling the problems of servomechanism design, manufacture, and operation. Gives essential data on circuitry, electrical, and mechanical components . . . shows what to do about these components to achieve the limit of their performance. Revised edition includes information on transistor amplifiers and transistor mag amps, gyroscopes, accelerometers, and other developments. **By W. R Ahrendt, U. of Maryland; and C. J. Savant, Jr., American Electronics, Inc. 2nd Ed., 566 pp , 515 illus., $12.50**

FEEDBACK CONTROL SYSTEM ANALYSIS AND SYNTHESIS

Just Published—Treats feedback control systems in a logical manner, unifying the diverse methods of analysis, and presenting fundamentals explicitly and clearly. Explains principles of obtaining differential equations for electrical, mechanical, hydraulic and heat flow systems. Takes up various methods of analysis such as root locus and frequency techniques, and compensation techniques. **By John D'Azzo, and and C. Houpis, Assoc. Profs. of Eng., Air Force Instit. of Tech. 566 pp., 484 illus., $13.50**

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MEETINGS

ference and Show, Statler-Hilton Hotel, New York May 23-26

International Instruments, Electronics, and Automation Exhibition, Olympia, London, England May 23-28

Institute of Radio Engineers, Seventh Region Conference, Seattle, Wash. May 24-26

Conference on Automatic Computing and Data Processing in Australia, University of Sydney, University of New South Wales May 24-27

JUNE

Instrument Society of America, Sixth Annual Instrumental Methods of Analysis Symposium, Montreal, Canada June 1-3

American Society of Mechanical Engineers, Semi-Annual Meeting and Aviation Conference, Statler-Hilton Hotel, Dallas, Tex. June 5-9

Material Handling Institute, New England Show, Commonwealth Armory, Boston, Mass. June 6-8

American Institute of Electrical Engineers, Summer General Meeting, Atlantic City, N. J. June 20-24

Second National Conference on Electronic Standards and Measurements, sponsored by National Bureau of Standards and IRE, National Bureau of Standards Laboratories, Boulder, Colo. June 22-24

Institute of Radio Engineers, Fourth National Convention on Military Electronics, Sheraton-Park Hotel, Washington, D. C. June 27-29

International Federation of Automatic Control, First International Congress on Automatic Control, Moscow, U.S.S.R. June 27-July 6

JULY

Seventh Annual Symposium on Computers and Data Processing, Denver Research Institute of University of Denver, Stanley Hotel, Estes Park, Colo. July 28-29

AUGUST

Fourth National Heat Transfer Conference and Exhibit, sponsored by AIChe and ASME, Statler Hotel, Buffalo, N. Y. Aug. 14-17

Western Electronic Show and Convention (WESCON), Ambassador Hotel and Memorial Sports Arena, Los Angeles, Calif. Aug. 23-26

WHAT'S AVAILABLE IN REPRINTS

The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient filable form. Some reprints are individual articles, while others are "packages"—several articles published over a period of time that logically supplement one another in the coverage of a specific phase of the control field. Any reprint can be obtained at the nominal cost listed below by filling in the order form and sending it, together with remittance, to Readers Service Dept. Quantity rates will be quoted on request.

Six Transducers for Precision Position Measurement, May 1960, 6 pp. Explains operation and gives practical application hints for six precision position transducers: pin-and-pawl mechanism, magnetic bench-mark system, resolver-type transducer, electrostatic transducer, coded-disc devices, and diffraction gratings. 30 cents.

Ready Reference Data Files—I, II, III, 76 pp. The feature here is a special rate for those who purchase all of the Data Files published in CONTROL ENGINEERING through April 1960. The 36 articles included in this package cover analysis, design, and application short-cuts for all phases of the control field. Everyone can use this timeless reference material. $1.35.

Ready Reference Data Files—III, 28 pp. Includes the third dozen Data Files published in CONTROL ENGINEERING. Topics range from control of metal properties with eddy currents to electrically signaled valve actuators to stabilization of sampled data systems. 60 cents.

Continued on page 209

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Ready Reference Data Files—II, 24 pp. Includes the second dozen data files published in Control Engineering. Topics covered range from analyzing hydraulic servos graphically to using silicon diodes as protective devices. 50 cents.

Ready Reference Data Files—I, 24 pp. A must for every control engineer's library. Includes the first 12 data files published in Control Engineering—a diversity of topics, from system reliability through the cost of industrial temperature-measuring systems. Each one gives a method of solving a particular problem, 50 cents.

How to Specify Instrument Accuracy, 8 pp. This basic reprint is aimed at helping the user and maker to develop clear and mutual agreement on allowable instrument errors. Discussions of uncertainties of zero, scale factor, and instantaneous slope aid in the intelligent specification of allowable errors and preferred test procedures. 40 cents.

Transparent Template for Designing Servo Compensators, November 1959, 3 pp. plus template. Includes transparent decibel vs phase angle template on clear acetate in addition to three-page Data File outlining development of template and showing its use through sample problem. 75 cents.

How to Use the Root Locus in Control System Design, 12 pp. Another reprint that translates theory into practice. Eight simple rules make locus construction easy, even including the effects of distance-velocity lags. Articles show how to interpret the locus diagram, how to determine transient response, and how to use locus techniques with multiloop systems. 45 cents.

Complete Analysis Instrumentation Series, 112 pp. Special rate for those who order all three parts (I, II, and III) of Analysis Instrumentation Series; 17 percent discount on 112 pages of timely technical information for process control engineers. $1.75.

Analysis Instrumentation—III—Electrochemical Methods, Mass Spectrometry, Continuous Viscometers, X-Ray Techniques, K-Capture, Physical and Chemical Property Testers, Emission Spectroscopy, 48 pp. Reprint includes last nine articles of Analysis Instrumentation Series. $.90.

Analysis Instrumentation—II—Refractometers, Infrared Analyzers, Photometric Analyzers, Colorimetry, 32 pp. This includes the second group of four articles of the Analysis Series. 60 cents.

Analysis Instrumentation—I—Nuclear Magnetic Resonance, Chromatography, Radioactivity, 32 pp. Reprint consists of first 4 articles of Analysis Instrumentation Series: a general introduction and detailed discussions of the three analysis techniques. Emphasis is on basic principles, practical tips, and the use of these techniques in automatic process control. 60 cents.

Fundamentals of Multivibrators, 12 pp. Multivibrators are the electronic equivalent of the double-throw electromechanical relay and can perform substantially the same functions (memory, logic, gating, counting), but at enormously higher speeds.

Continued on page 210

REPRINTS cont'd

They can be built around vacuum tubes, transistors, square-loop magnetic materials, neon tubes, thyratrons, and cryotrons. This reprint covers a broad selection of multivibrator circuits. 45 cents.

A Roundup of Control System Test Equipment, 24 pp. Specialized control system test equipment divides into three classes: 1) devices that only generate a test signal, 2) systems that both disturb the system and provide a means for evaluating response, and 3) devices that only evaluate control system response. 60 cents.

Survey of Ac Adjustable-Speed Drive Systems, June 1959, 16 pp. Regarded as constant-speed devices, multispeed ac actuators actually take many efficient forms. The recent resurgence of interest in these ac adjustable-speed systems prompted this comprehensive coverage of pole-changing techniques, armature resistance control of wound-rotor motors, frequency changing, slip-frequency injection, and the use of eddy-current couplings. 50 cents.

A New Way to Select the Best Control Valve, 16 pp. This three-article reprint takes a fresh look at the problem of specifying process flow control valves. The author gives rules for selecting the right valve characteristics based on static and dynamic considerations, takes into account the influence of piping on valve performance, and tackles the problem of sizing valves for maximum flow and for control rangeability. 50 cents.

Fundamentals of Tie-Motor Control, 12 pp. Although high-powered synchro-tie systems have been around for a long time, only recently has enough experience been logged to put their design on a scientific, rather than cut-and-try, basis. This reprint examines the types of motors that can be used in the light of the application characteristics, and considers the special circuit designs that are required. 30 cents.

Applying Phase-Plane Techniques to Nonlinear System Design, 16 pp. This series of three articles is designed to teach the use of phase-plane techniques to working system designers, on a practical rather than theoretical basis. It tells how to construct a phase-plane plot, interpret a pilot in terms of system performance, and synthesize nonlinear systems using phase-plane techniques. 50 cents.

Economics in Control, December 1958, 24 pp. A special report covering the economic aspects of modernizing with control systems. It starts off with a guide to the financial factors of modernization, then tells the control engineer how to spot opportunities where the addition of instrumentation and control equipment will earn money, and concludes with nine case histories showing specific benefits of modernizing with control systems. 50 cents.

Static Switching Devices—New Tools for Industrial Control, May 1957, 28 pp. An independent consultant analyzes the complete field of industrial static-switching systems. Starting off with a review of basic switching logic, he covers circuit characteristics of the fundamental devices, commercially-available systems, actual applications, etc. 50 cents.

Continued on page 211

REPRINTS cont'd

How to Calculate a Control Earning Index, 12 pp. Shows a four-step method for predicting the increment of improved plant economy resulting from the addition of instruments and controls, and reports on experience in applying this method to three typical industrial processes. 30 cents.

Servo Design Techniques, 32 pp. A reprint of six related articles describing various electromechanical servo design techniques. Items include tachometer limiting, force-reflecting servos, calculating performance of drag-cup tachs, dual-mode servo compensation, applying packaged servo actuators, and cascading resolvers without amplifiers. 65 cents.

What's Available in Flowmeters, 24 pp. A comprehensive coverage of positive displacement, velocity, and mass flowmeters, including characteristics, applications, and typical manufacturers; plus details of a special drag disc meter. 50 cents.

Selecting and Applying Control Timers, 24 pp. A compilation of four articles including a tabular description of timer functional parts, criteria for selecting and applying control timers, a tabular listing of available timer types and their characteristics, and techniques for custom-designing controls for time-based routines. 50 cents.

What the Control Engineer Should Know About Reliability, April 1958, 8 pp. Not intended as a comprehensive treatise, but rather as a guide to aim the control engineer in the right direction, this staff-written article discusses the new concept of systems effectiveness, and briefly covers techniques for measuring reliability, predicting reliability, improving reliability, and costing reliability. Up to date reference sources increase the value. 20 cents.

Servo Modulators—Their Application, Characteristics, and Availability, 36 pp. A group of four integrated articles covering all phases of electromechanical, electronic, solid-state, and magnetic modulators. Typical circuit diagrams, characteristics, and applications are given for each type, plus an 84-item bibliography and tables listing commercial units. 65 cents.

Basic Data on Process Control, 24 pp. A grouping of five articles on flow-process control, including Basic Concepts of Feedback Control, Selecting Loops for Critical Control, Direct or Reverse Controller Actions, Modifying Valve Characteristics to Fit the Process, and Using Capacitance for Accurate Level Measurement. 50 cents.

How to Simulate Dead Time, 6 pp. Three tricky techniques for simulating dead time or transport lag. One's electronic, another is pneumatic mechanical, and the third uses magnetic tape. A useful reference for control engineers concerned with process simulation. 15 cents.

Transistor and Thyratron Power Amplifiers, 28 pp. These three articles—one on transistors and two on thyratrons—were prompted by the increasing control application of transistors at low-power amplifiers and thyratrons as high-power amplifiers. In each case the emphasis is on practical application, circuit design, system stabilization, etc. 50 cents.

• • •

Checklist for Progress, Yours and Ours

✓	**GROWTH**—in General Electric's process instrumentation program, closely tied to growing field of industrial automation and related technologies.
✓	**PRODUCT DIVERSITY**—work on wide range of products for continuing needs of many industries for complex sensors, controllers. recorders, other electronic devices and systems.
✓	**CREATIVE DIVERSITY**—development of fundamentally new primary detectors, including means for sensing pressure and flow, requires new technologies. Basic broad nature of measurements closely related to industrial growth.
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MECHANICAL ENGINEERS—for design of transmitters involving diaphragms, bellows, Bourdon tubes. B.S. in M.E., 5 years in design of differential pressure and flow detectors.

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For Further Information . . .
please write in confidence to: Mr. H. E. Crabtree, Manager, Engineering Administration,

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Duties include preliminary analysis, design and development of experimental equipment and the design and testing of prototypes. Working knowledge of automatic controls for industrial machinery, high voltage rectifier equipment or high voltage gaseous discharges desirable. Some design and development experience required.

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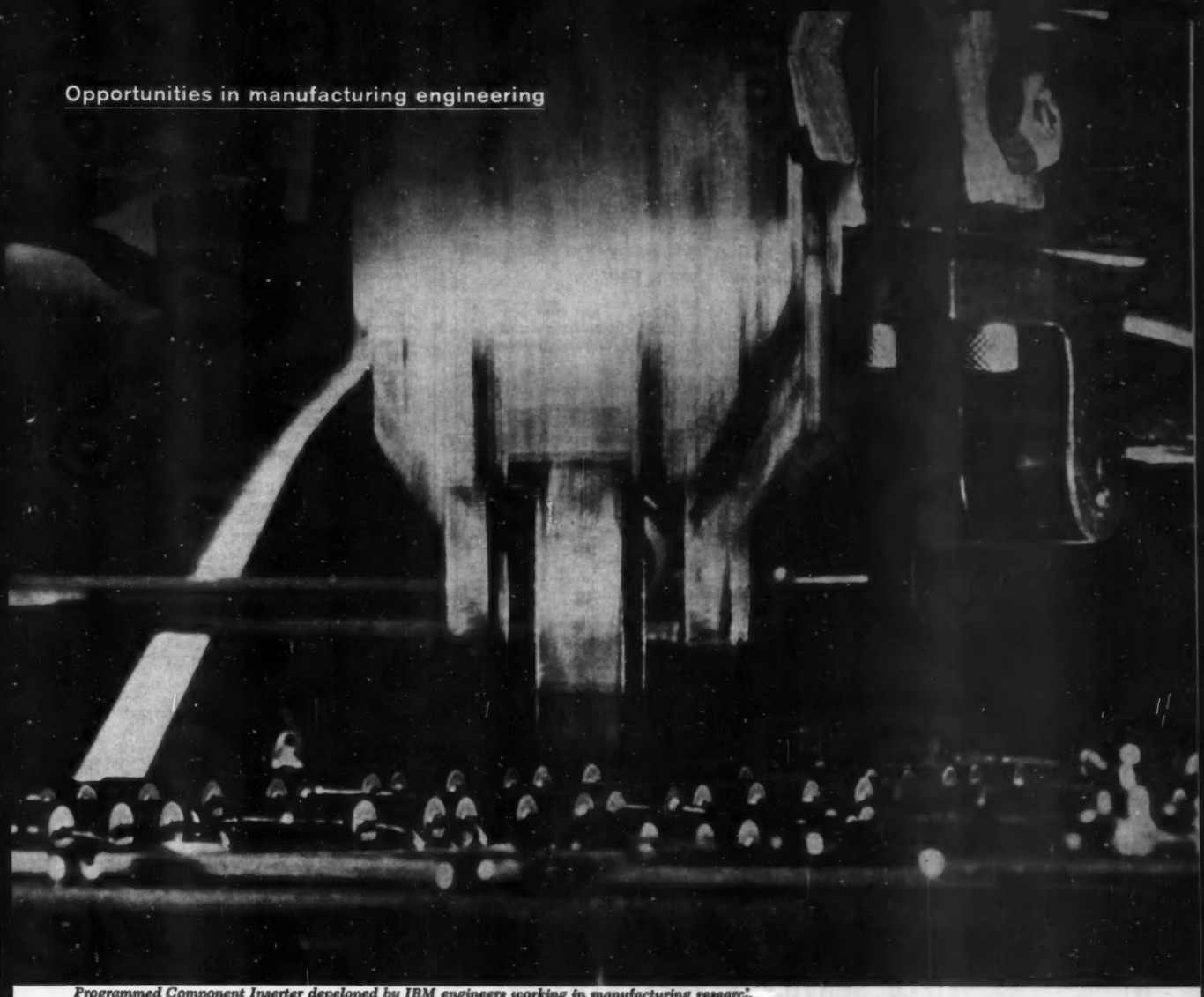
Opportunities in manufacturing engineering



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Engineering complete assembly cycles down to 1.2 seconds

In the time it takes you to read this sentence, the Programmed Component Inserter can select, position, insert, and then clinch four or five different electronic components onto a printed circuit board. This system makes possible low-cost assembly of pluggable logic units for computer applications.

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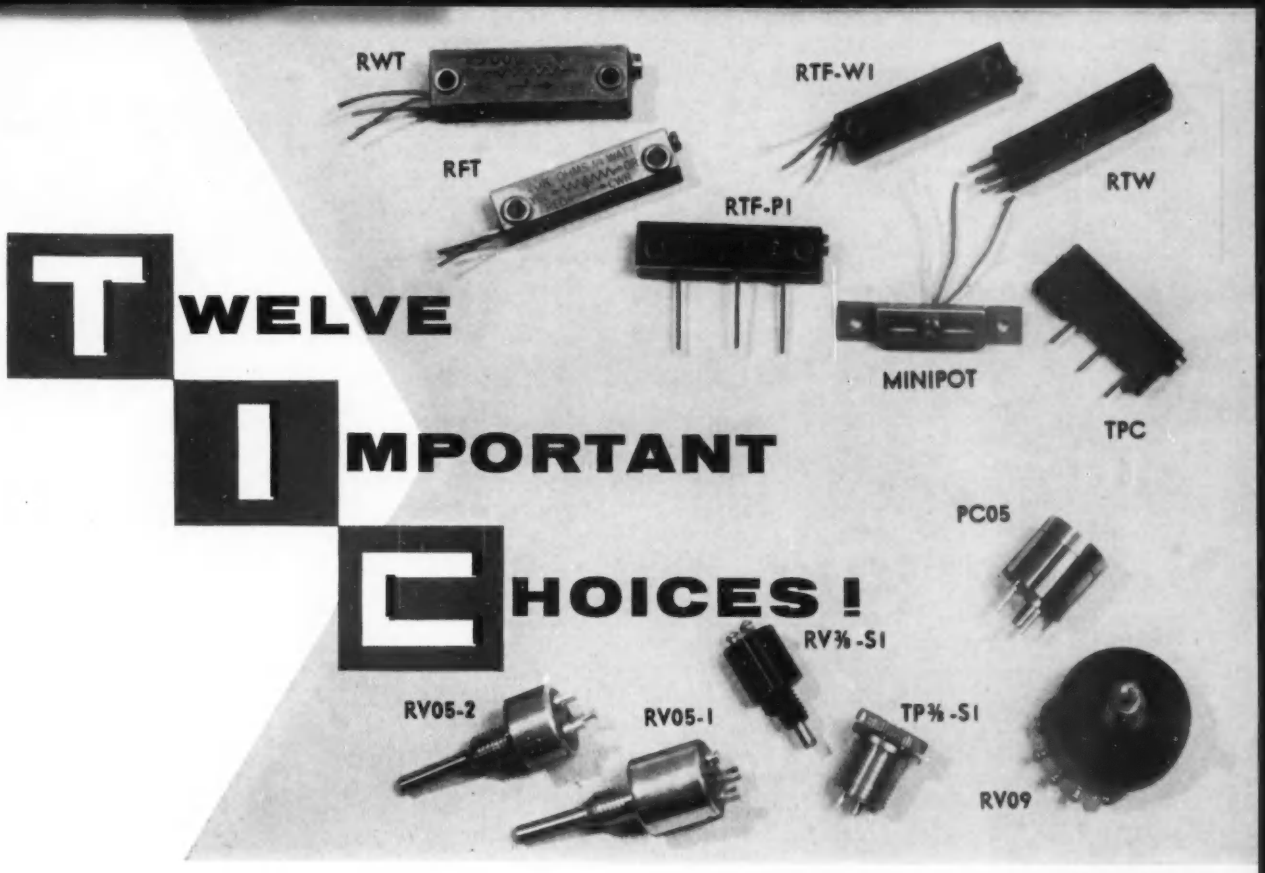

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PRECISION TRIMMER POTENTIOMETERS by TIC are standard in twelve different styles and each in a wide range of resistance values. The extensive use of trimmers in such applications as airborne, shipborne and ground based military electronic equipment for navigation, flight control, fuel control, radio transmission and reception, telemetering, computers, fire control and many others demands reliability and stable operation under severe environmental conditions. TIC quality-control procedures and environmental testing assure the user of the ultimate in dependable trimmer potentiometers.

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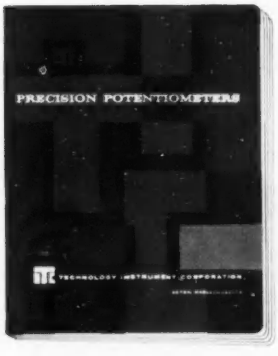

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Isolation between Adjacent Channels at 5 Mcps Spacing	≥20 DB
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